UMTRI-87-32

UPGRADING THE SUSPENSION MEASUREMENT FACILITY

Final Technical Report

(MVMA Project # 6162)

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July 1987

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-87-32		

4. Title and Subtitle
UPGRADING THE SUSPENSION MEASUREMENT FACILITY

5. Report Date
July 1987

6. Performing Organization Code

7. Author(s)
C.B. Winkler and M.R. Hagan

8. Performing Organization Report No.
UMTRI-87-32

9. Performing Organization Name and Address
The University of Michigan
Transportation Research Institute
2901 Baxter Road, Ann Arbor, Michigan 48109

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
MVMA Proj #6162

12. Sponsoring Agency Name and Address
Motor Vehicle Manufacturers Association
300 New Center Building
Detroit, Michigan 48202

13. Type of Report and Period Covered
Final
7/1/86-6/30/87

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
UMTRI has upgraded its Suspension Measurement Facility by adding a digital data-acquisition system to the original analog instrumentation. The addition of this system has improved the efficiency of the facility roughly twofold, allowing reductions of similar magnitude in time required for testing. Additionally, the data describing the response of the tested suspension can now be made available on readily transportable magnetic medium, in IBM-PC-compatible files. Programs for the convenient display and reduction of these data are available. These data reduction programs are hardware specific in that they require that a particular commercially available "graphics card" be used in the computer system.

17. Key Words	18. Distribution Statement
parameter measurement, digital data-acquisition system, suspensions	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None		

TABLE OF CONTENTS

INTRODUCTION

The University of Michigan Transportation Research Institute (UMTRI) has upgraded its Suspension Measurement Facility by adding a digital data-acquisition system to the original analog instrumentation. The addition of this system has improved the efficiency of the facility roughly twofold, allowing reductions of similar magnitude in the time required for testing and test costs. Additionally, the data describing the response of the tested suspension can now be made available on a readily transportable magnetic medium, in IBM-PC-compatible files. Programs for the convenient display and reduction of these data are available. These data reduction programs are hardware specific in that they require that a particular commercially available "graphics card" be used in the computer system.

The UMTRI Suspension Measurement Facility, shown in Figure 1, is a one-of-a-kind device developed under Motor Vehicle Manufacturers Association (MVMA) support by UMTRI. Because of its uniqueness, numerous organizations, including domestic and foreign vehicle manufacturers, make use of this facility to obtain data needed for understanding vehicle ride and handling behavior.

The Suspension Measurement Facility is capable of measuring virtually all of the compliance, kinematic, and Coulomb friction properties of suspension and steering systems as they react to vertical force, roll moment, lateral force, brake force, and aligning moment. The facility can accept single-axle and tandem-axle suspensions (maximum tandem spread 70 in) of all common, on-highway track widths. Suspensions can be tested in their normal configuration (mounted on a vehicle), or as mounted on an abbreviated frame section. All measurements are performed at steady-state or quasi-steady-state; that is, the facility is not intended for dynamic testing.

The facility has 48 instrumentation channels previously handled exclusively by analog circuitry and recording devices. This arrangement resulted in the operator spending a great deal of test time dealing with instrumentation calibration, etc. The addition of an automated, digital data-acquisition system has enhanced the efficiency of this test facility and improved the flexibility and transportability of the resulting data.

Data reduction software has been developed for manipulating test data stored on either magnetic tape, hard disk, or floppy disk. These programs allow for the convenient calculation and display of "derived" variables from calculations based on the "primary," or

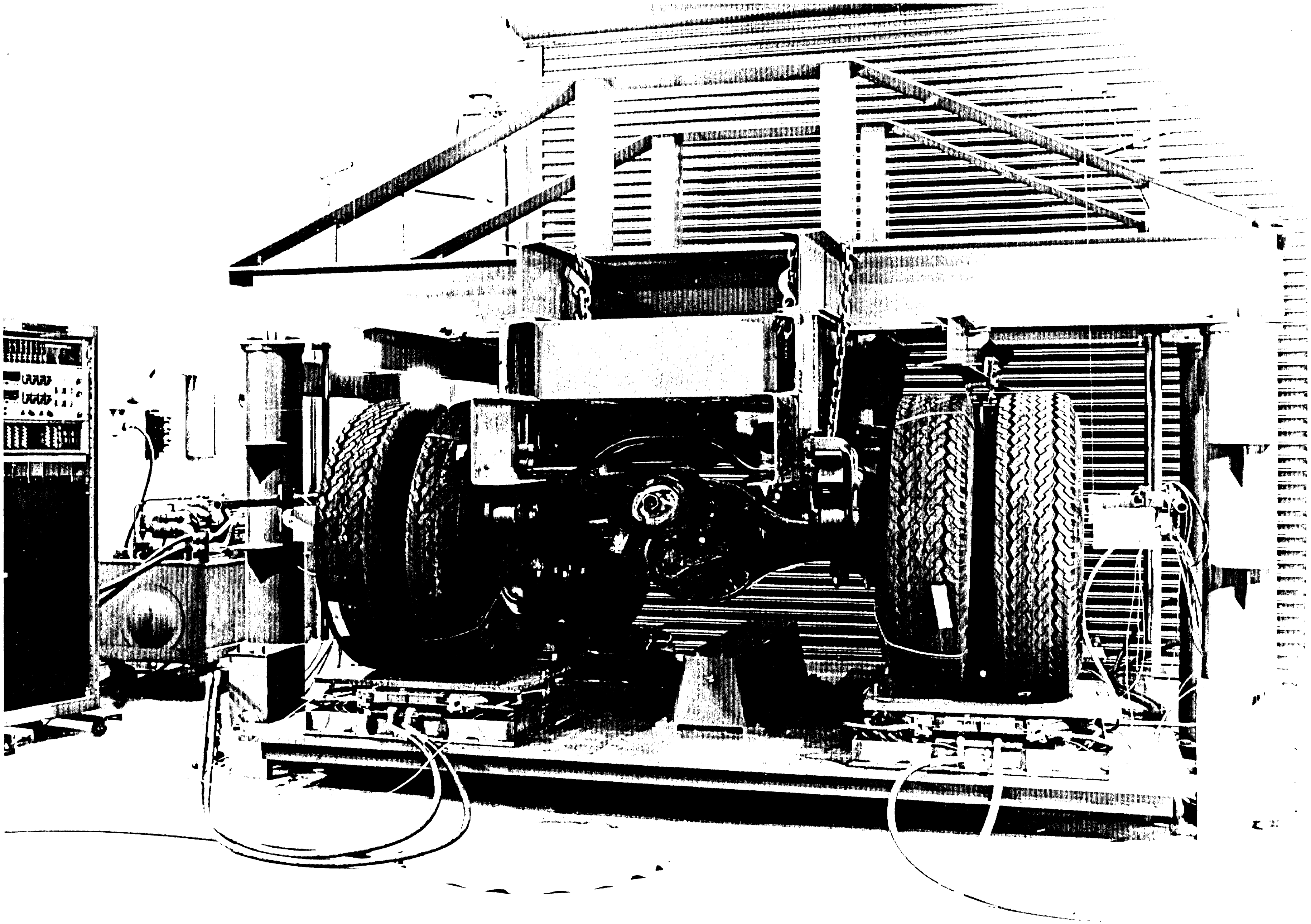


Figure 1. UMTRI Suspension Measurement Facility

measured variables. The programs include graphic aid techniques for reducing data to simulation parameters.

SYSTEM HARDWARE

Overview

The main electronic elements of the Suspension Measurement Facility are diagrammed in Figure 2. The old system consisted of 12 circuit cards, 8 of which provided the signal conditioning for the various transducers. Three new card racks, containing 16 amplifier cards each, now provide the signal conditioning for the facility. The transducer outputs are routed to the new elements by jumper cables plugged into the slots for the old system. Similarly, the outputs of the new cards are jumpered back into these slots so that the pre-exisitng signal chain is maintained. These outputs can be monitored via DVMs or other devices by placing plugs in the appropriate holes in a test jack panel provided. The analog circuitry associated with the servo control systems of the facility remains unchanged by the new system.

In the old system, gain and offset adjustments for each of the data channels were done by manually turning pots and throwing dip switches. Signal outputs from the experiment were displayed using an X-Y plotter. The new system is controlled by an IBM-PC-based acquisition system which is connected via a 48-channel A/D interface to the analog outputs. The X-Y plots, formerly plotted on the analog recorder, are now viewed on the CRT screen and screen dumps are used to obtain hard copy. The operator can select two channels for the X-Y plots and up to four monitor channels to display during a test. Feedback mode switching is augmented by a computer function which calculates and displays the correct command pot settings for any mode switch. Data from all 48 channels are collected and stored digitally for later reduction. The computer also automatically adjusts the zero data voltages and measures and records the amplifier gains.

The following section describes the hardware components used in the Suspension Measurement Facility. The computer components described briefly in this section are commercially available products that include detailed documentation provided by the manufacturers. For this reason, only the UMTRI-supplied hardware (analog signal-conditioning unit and ITM interface card) is described in detail.

Digital Hardware

The Computer System. An IBM-PC is the heart of the Suspension Measurement Facility, serving to control its calibration, operation, data acquisition, data processing, and data viewing. An ADIC Model 550 tape recorder system is used for recording the measured data. It is a 64-megabyte cartridge recorder capable of recording at up to 35k Hz,

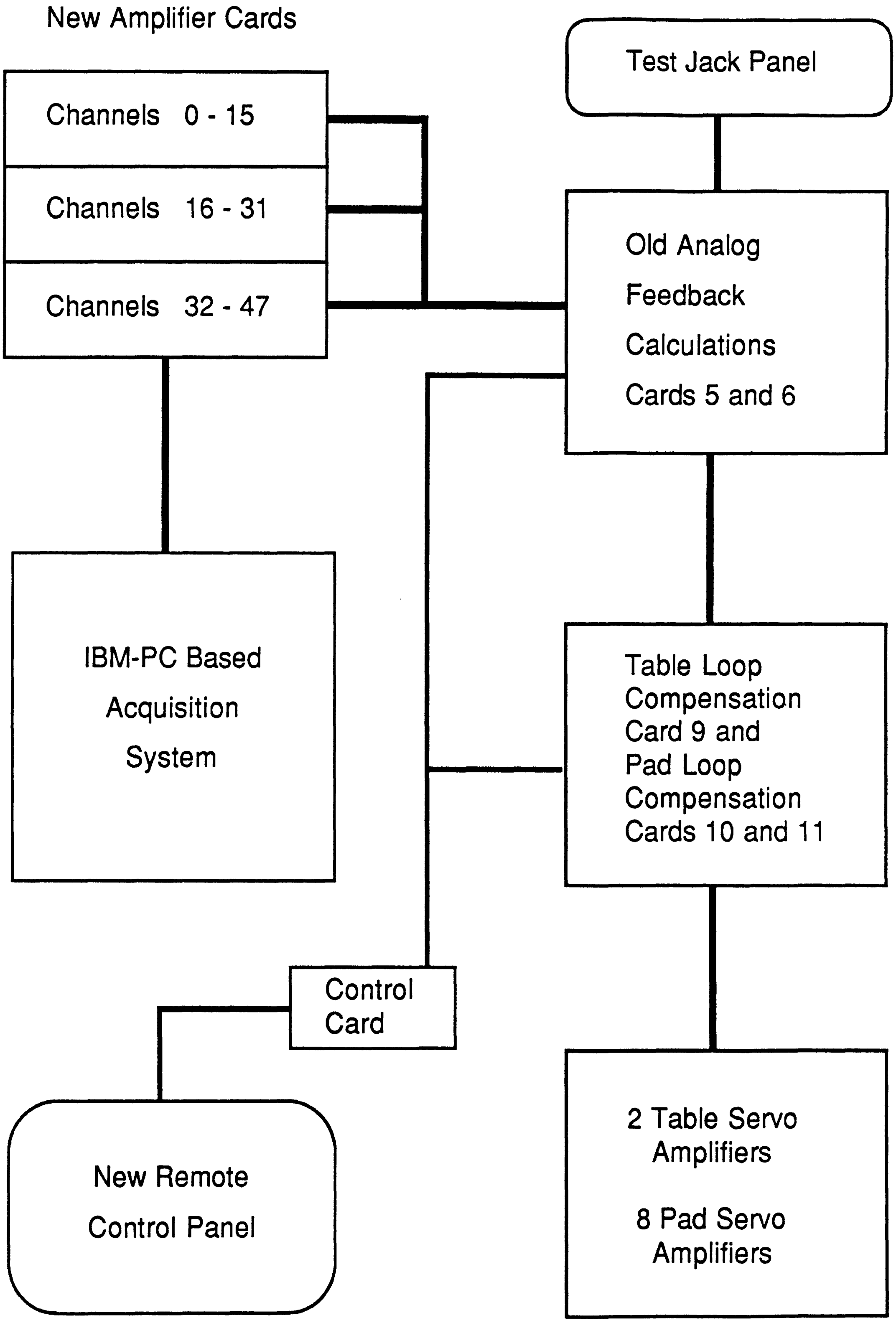


Figure 2. Diagram of System Hardware

which appears as four hard disk drives to the computer. The PC is a standard commercial version with the following components:

- IBM-PC, 256k memory, 2 DS DD floppy disk drives, and floating point processor
- Hercules graphics card and IBM monochrome monitor
- AST Six Pack Plus with 384k memory, clock, serial port, and parallel port
- Metrabyte Quad D/A board
- A/D input board (custom-built)
- Citizen dot matrix printer (IBM-compatible)
- ADIC tape control card
- IBM interface card (custom-built with the signal-conditioning unit)
- "Hardcard 20" 20 mb hard disk

A Tecmar expansion chassis is required with the PC to accommodate all of the extra cards. Figure 3 shows an overview of these components.

The AST Six Pack Plus supplements the computer memory to the limit of 640k, and the parallel port is used to drive the printer. The A/D is the custom analog-to-digital converter system. It has 48 single-ended inputs and is capable of digitization at 50k Hz. The ADIC tape control card is purchased from the tape manufacturer, and is used to control the tape recording system.

A/D Board. The Suspension Measurement Facility has a custom-built A/D board for two reasons. The first is purely economic. The old system already contained a 16-channel A/D module with a 32-channel expansion multiplexer. Secondly, commercial 48-channel systems are hard to come by and, if available, are awkwardly configured.

The custom A/D board is diagrammed in Figure 4. Two Datel modules, an MDAS-16 and an MDXP-32, comprise the heart of the A/D interface. The MDAS-16 contains a 12-bit A/D converter, sample and hold amplifier, tri-state output registers, conversion logic, and a 16-channel multiplexer (connected to channels 0-15 of the facility). The MDXP-32 module supplies a 32-channel analog multiplexer (connected to channels 16-47 from the facility), address latches, external mux enabling, and address decoding to bring the total channel capability to 48 channels.

IBM Interface Card. The IBM interface card plugs into either the IBM-PC or the expansion chassis. It is a prototyping card with wire-wrapped connections. The card contains the interface to the IBM address and data buses, circuitry to control the signal-

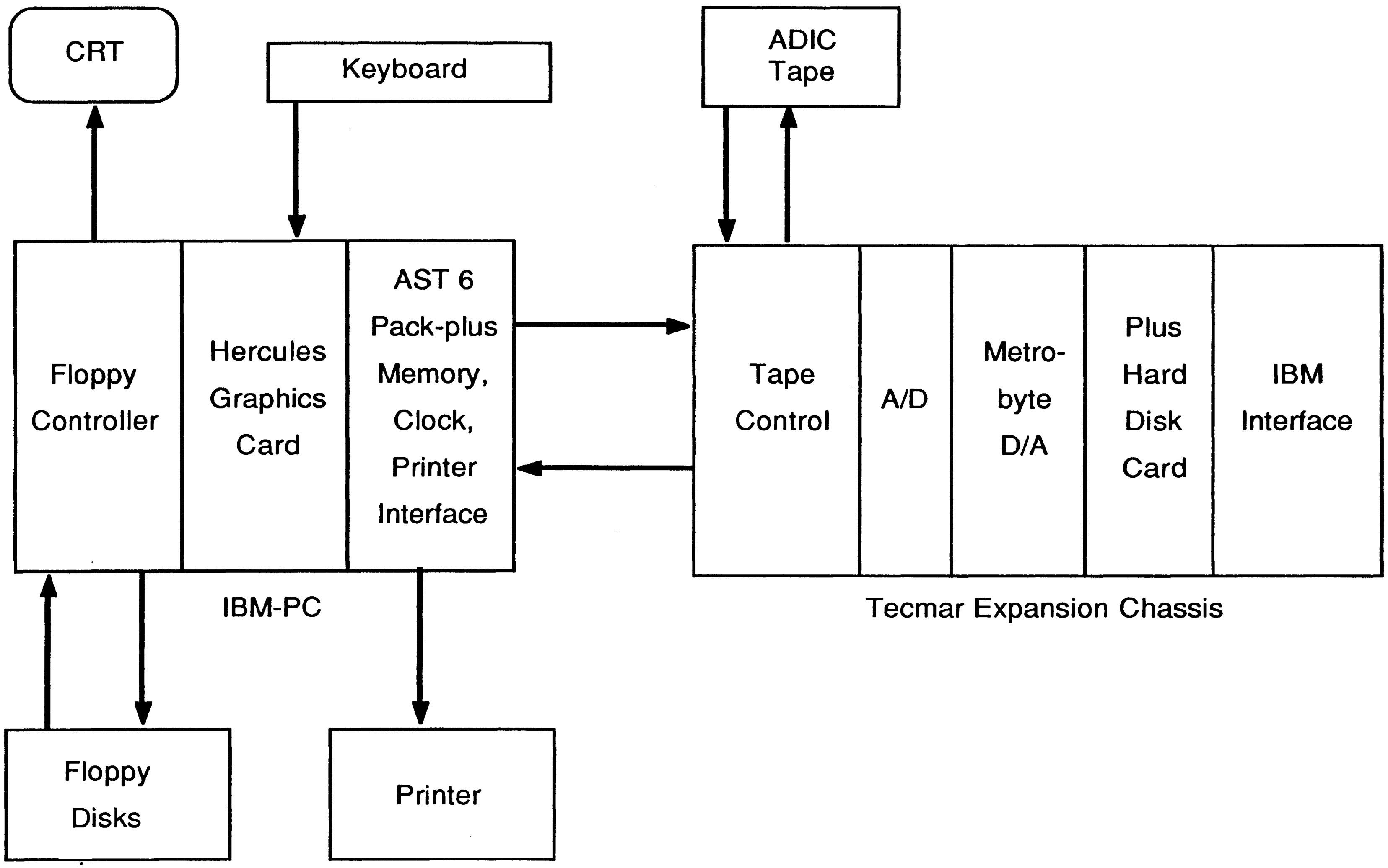


Figure 3. Digital Elements of Suspension Measurement Facility

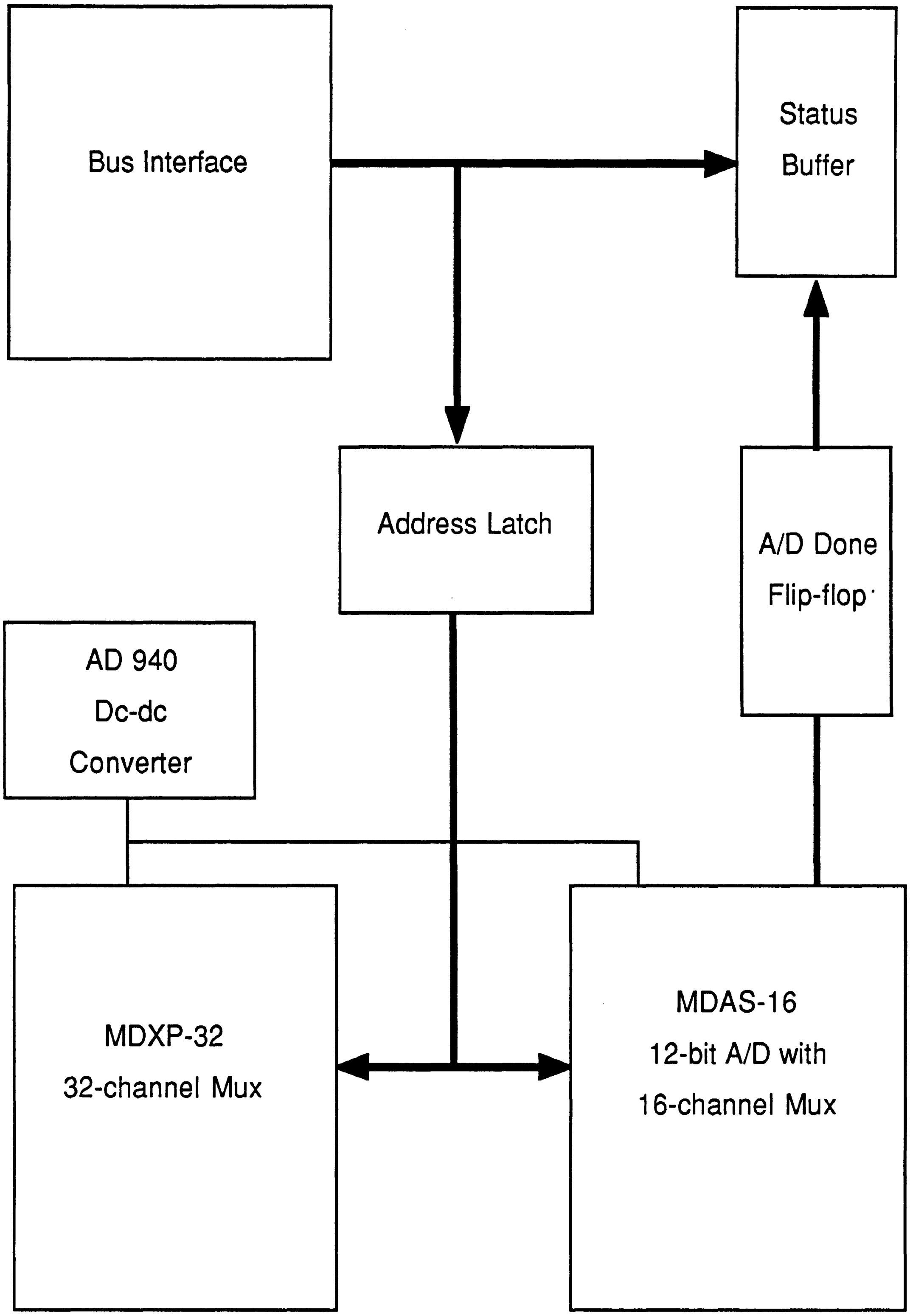


Figure 4. Diagram of A/D Board

conditioning unit, A/D interrupt circuitry, and a switch debounce. Figure 5 shows the block diagram of the IBM interface card.

In the bus interface, two decoder/demultiplexer chips provide the address selecting for the card. An octal bus transceiver buffers the data lines and an octal buffer/line driver supplies the bus control signals. Finally, a dual D-type flip-flop connects the output of the A/D sample counter to the PC interrupt controller.

The AM 9513 system timing controller provides the A/D sample triggering and the debouncer clock. This chip includes 5 general-purpose, 16-bit counters. In the Suspension Measurement Facility application, the counter provides a data sampling frequency of 10 Hz. During calibration, a 100 Hz sampling frequency is used.

Data are saved by the software only when the "data switch" is depressed by the operator. To prevent "noise" problems, the switch is connected to a hex switch debouncer. The data switch condition must be stable for at least 4 clock periods before the output is allowed to change, and data-taking actually starts or stops.

The circuitry diagrammed on the right side of Figure 5 constitutes the signal-conditioning unit interface. All digital interface lines are opto-isolated to allow flexible power-up sequencing and to prevent ground loops in the analog interface. An 8255A Programmable Peripheral Interface chip provides both the address lines and the control signals for the signal-conditioning unit. One 8-bit latch interfaces the PC data bus to the signal-conditioning unit data bus and another provides the control signal for the calibration enable relay.

Analog Hardware

The analog part of the additions to the Suspension Measurement Facility consists of 3 analog backplanes, 48 signal-conditioning cards, 3 control cards, 3 pull-up cards, and the interconnecting cables.

Analog Backplane. The backplane is a custom-made printed circuit card that holds the connectors for the transducer inputs, signal-conditioning cards, control inputs, control card, and pull-up card. Also on the backplane are solder pads for the A/D and test jack wiring. Most of the connections between cards are accomplished with printed circuit traces, although some wire-wrapping is used. Figure 6 shows the layout of the backplane. Transducers are interfaced via the 9-pin connectors at the bottom. Two 25-pin connectors bring in the calibration control lines from the computer. The control card in the far left slot decodes these signals and distributes them to the remaining cards. The next 16 slots are for signal-conditioning cards. The last slot contains the pull-up card.

Analog Signal-Conditioning Card. A block diagram of an analog signal-conditioning card is shown in Figure 7. The transducer normally connects to the card via a

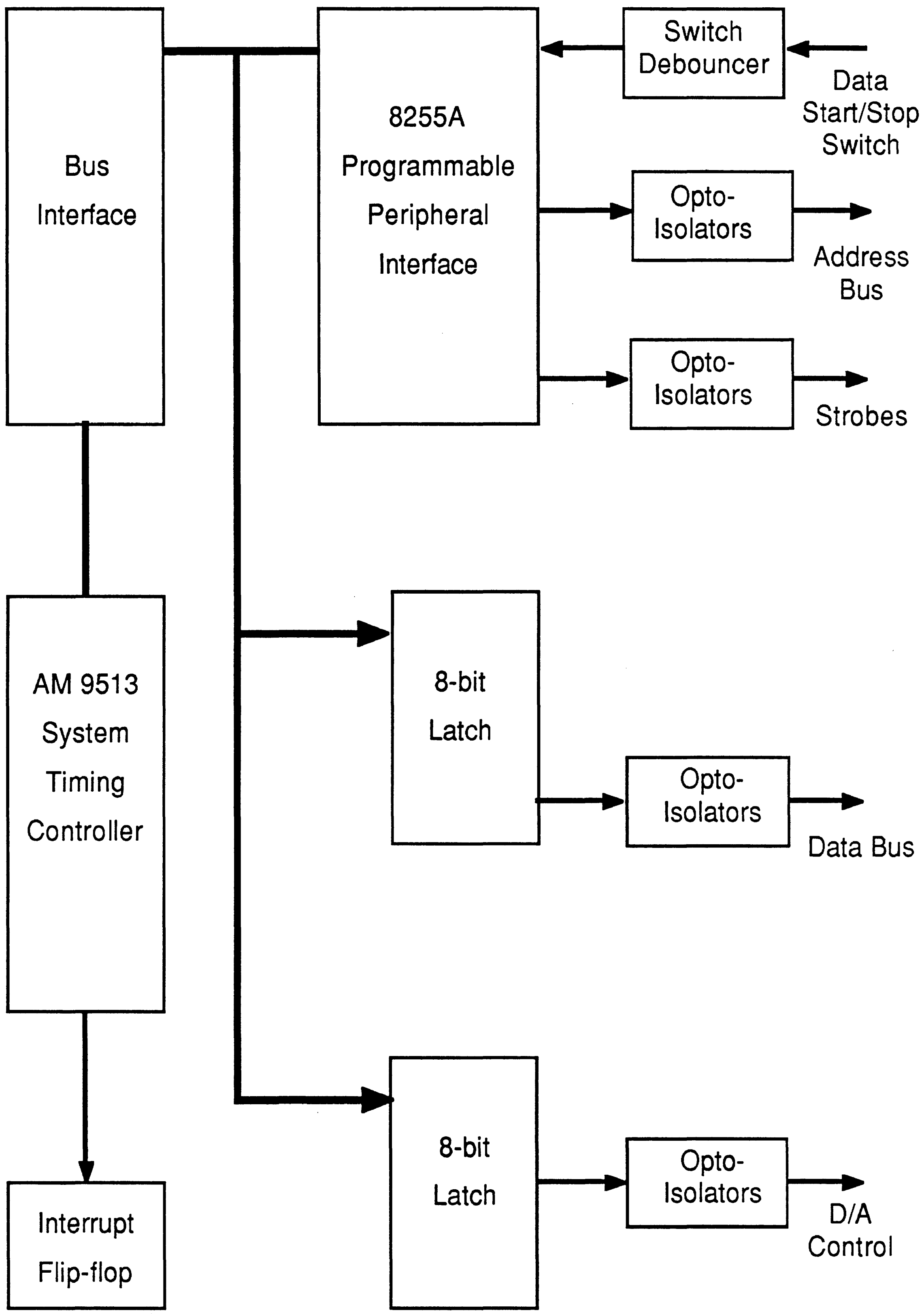


Figure 5. Block Diagram of IBM Interface Card

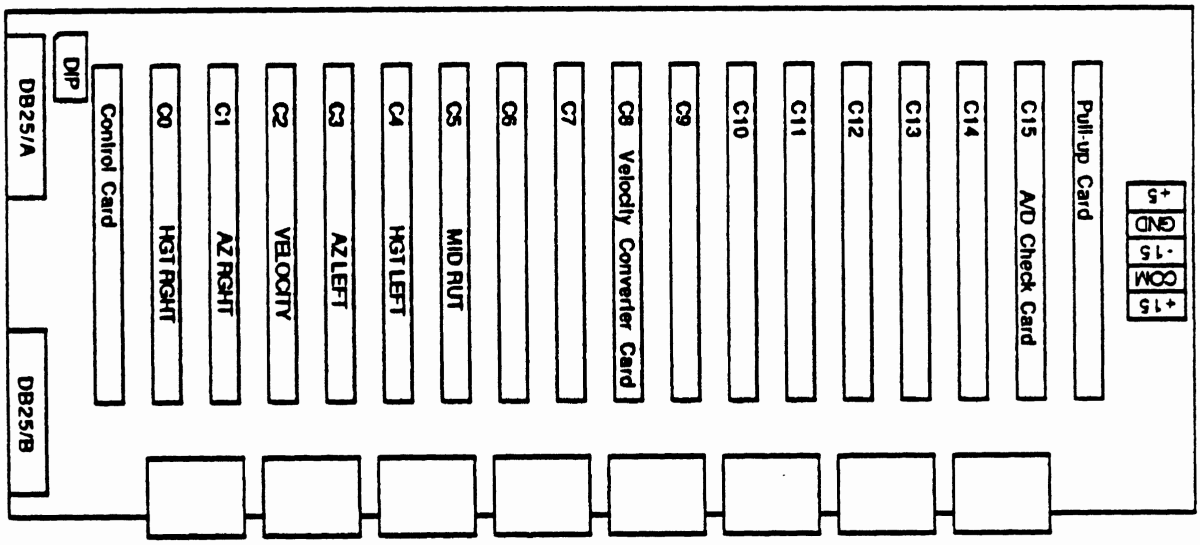


Figure 6. Backplane Layout

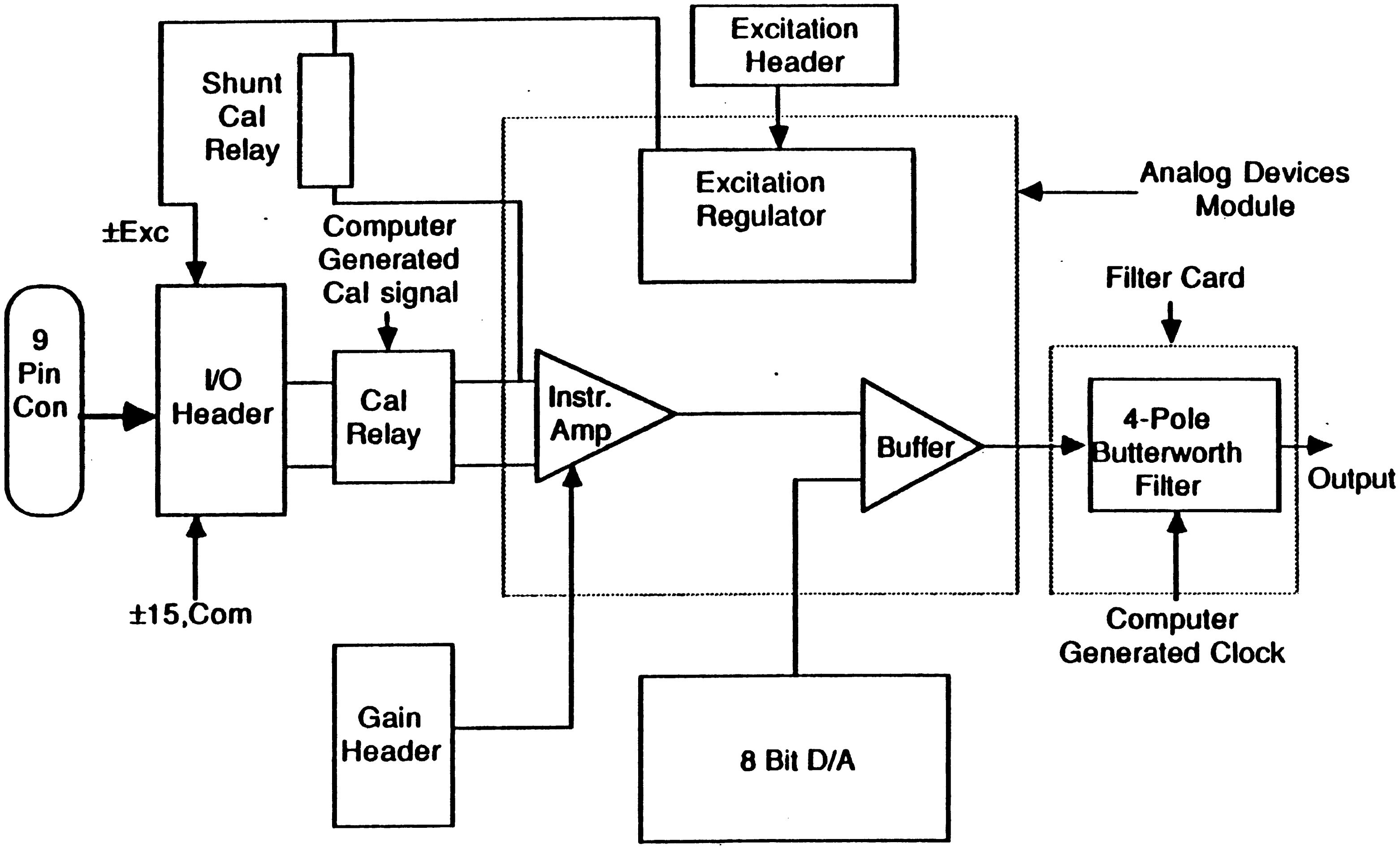


Figure 7. Diagram of Analog Signal-Conditioning Card

9-pin connector, but is hardwired in the Suspension Measurement Facility through the backplane and I/O header.

Jumpers on the I/O header provide for selecting the transducer's excitation and route the transducer outputs through the calibration relay to the instrumentation amplifier. The computer measures the gain of the card by switching this relay. For potentiometric devices, the inputs to the instrumentation amp from the transducer are disconnected and a D/A-generated calibration signal (staircase waveform) is inserted. The output of the card is measured by the A/D and the amplifier gain is calculated using a linear regression formula. The same hardware is also used for a strain gauge bridge, in which case the shunt cal relay is used to connect a resistor in parallel with one arm of the bridge. Because the voltage this generates is known to be equivalent to some force, the computer can calculate the overall system gain. Only one shunt cal relay or one cal relay (not both) are included in each signal-conditioning card, depending on the type of transducer being handled by the card.

The instrumentation amp, excitation regulator, and buffer amp in the dashed rectangle of the block diagram (Figure 8) reside in an UMTRI-designed plug-in module. The plug-in circuit module was designed to replace the Analog Devices 2B31 instrumentation module in the Suspension Measurement Facility application and for general-purpose data-acquisition applications. A diagram of the module is shown in Figure 8. The most important component on the board is a Burr Brown INA 104 integrated circuit that contains a very high-accuracy instrumentation amplifier and an uncommitted buffer amplifier. Because both inputs to the buffer amplifier are available (as opposed to the 2B31), the gain of the D/A offset can be adjusted by selecting an appropriate resistor. A 16-pin gain header provides the connection of an offset pot to the instrumentation amp, the gain setting resistor, the shunt cal resistor, and jumpering of the output of the instrumentation amp to the input of the buffer amp. The computer adjusts the offset voltage of the card by sending a digital value to an 8-bit D/A whose output is summed with the signal at the buffer amplifier.

Analog Control Cards. The analog control card occupies the far left slot on the backplane (see Figure 6). The address and strobe lines from the DB connectors are routed to this card, as shown in the block diagram of Figure 9. One decoder decodes the address lines and the calibration relay enable line into the 16 different relay control signals. One of these signals goes to each analog signal-conditioning card and either turns on or turns off the calibration relay. The second decoder decodes the address lines and D/A enable line into 16 different D/A enable lines. These lines enable the 8-bit data bus to be loaded into an offset D/A on the selected analog signal-conditioning card.

Pull-Up Card. The pull-up card occupies the rightmost slot on the backplane. This card contains a voltage reference that all of the offset D/A's use. Since all of the data bus lines come from optoisolators on the IBM interface board, pull-up resistors are required. These resistors reside on this card. In addition, the pull-up cards are used to connect the data lines among the three backplanes. The last pull-up card also has the cal D/A enable relay. This relay either presents analog ground to the Cal Hi and Cal Lo lines (when it is

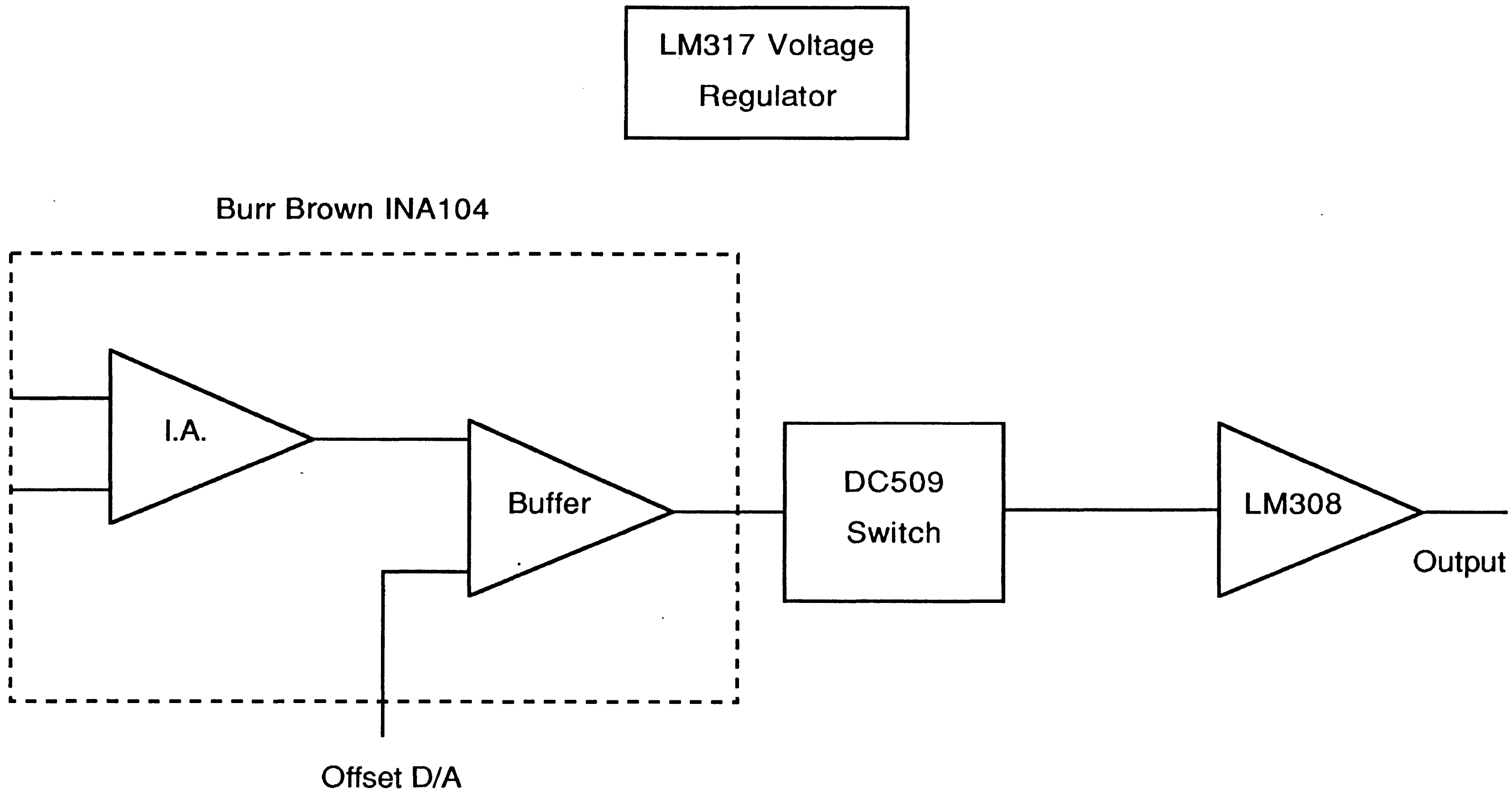


Figure 8. Plug-in Module

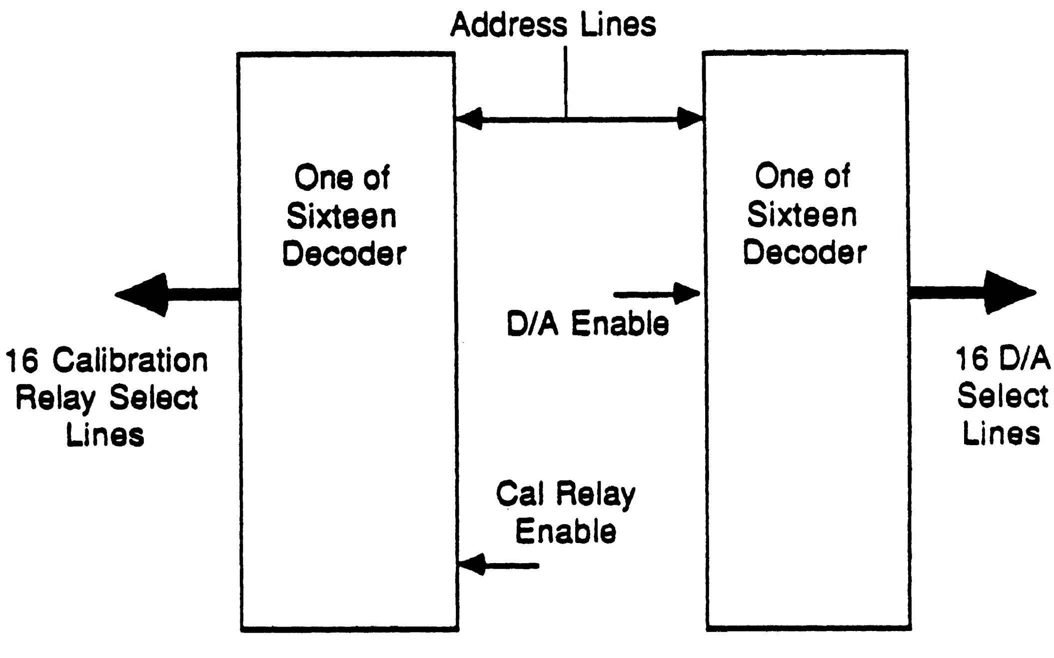


Figure 9. Analog Control Card Diagram

off) or connects the D/A to the Cal Hi lines (when it is on). An optoisolated control line from the IBM interface board switches the relay under software control.

Interconnections. Figure 10 shows how the three backplanes are connected. The optoisolated control lines (address, strobe, and data) originate from the IBM interface card and connect to the top (#1) backplane at the two DB-25 connectors (A and B). The signals required by the control card are routed by a 16-wire dip jumper cable from backplane #1 to control card #1. These lines are then daisy-chained to control cards #2 and #3 via similar 16-wire ribbon cables. The outputs of the cards are wire-wrapped as normal from the edge card connector. The other control lines (data bus, shunt cal, etc.) are connected to the backplane which busses them to all the cards, including the pull-up card. These bussed lines are daisy-chained to backplanes #2 and #3 via 16-wire ribbon cables that attach to the pull-up cards. In addition, a shielded twisted-pair cable connects the output of the D/A enable relay on pull-up card #3 to pull-up card #2 and then to pull-up card #1. A twisted pair also connects the IBM interface card cal control signal to pull-up card #3.

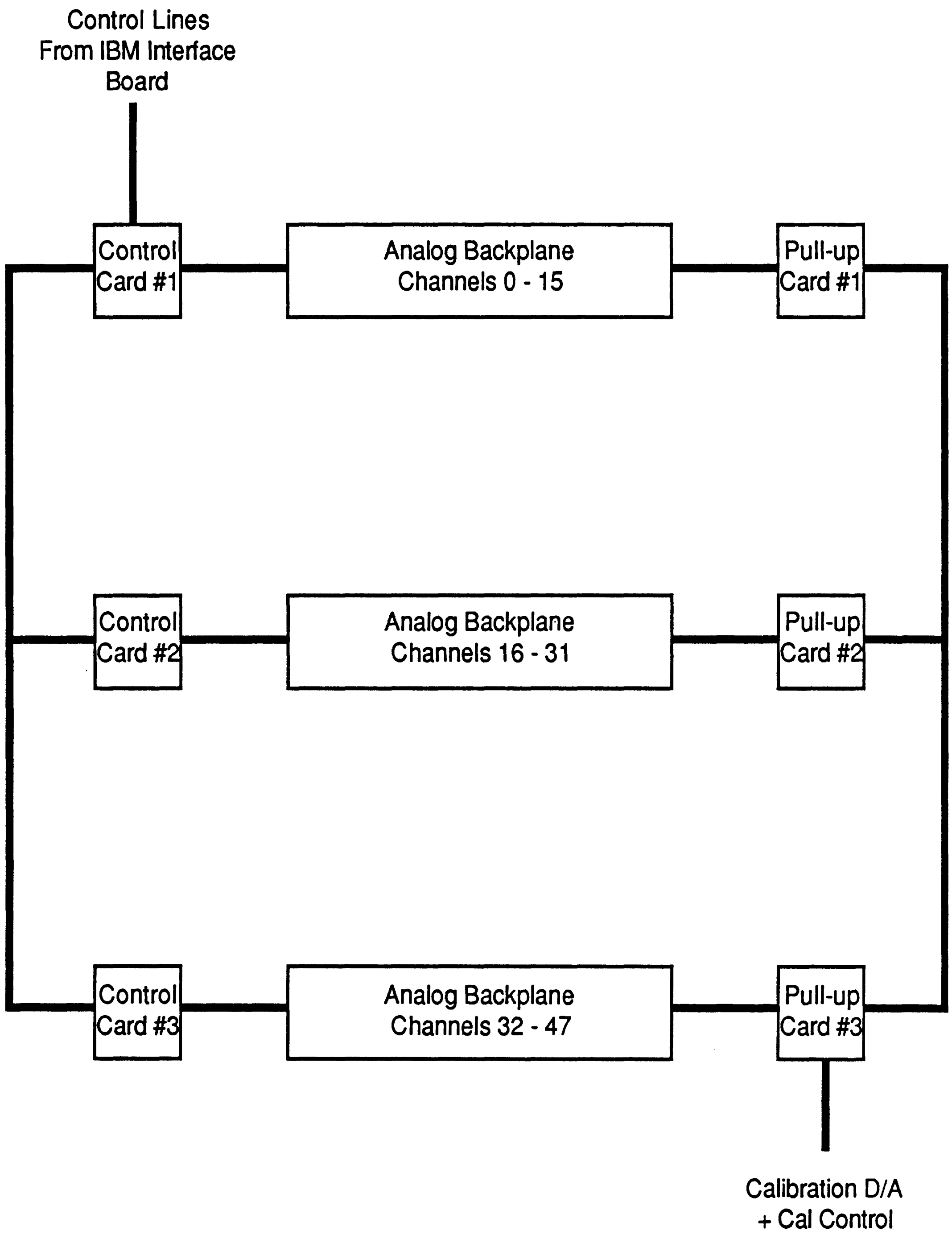


Figure 10. Analog Interconnections

DATA HANDLING SOFTWARE

In the testing process, data are gathered on a run-by-run basis and the data from each run are stored in an individual data file. A test 'run' is classified by the primary mode of suspension motion or loading; that is, there are vertical, roll, lateral force, longitudinal force, and aligning moment run types. Data from all channels are collected during every run so that a number of measures can be obtained from a given run. For example, one roll test run will provide data for roll rate, roll steer, and roll center height measures.

Each data file contains a substantial body of information beyond the data itself. The file includes a written description of the vehicle and/or suspension and certain geometric measurements of the facility and suspensions (e.g., lateral spring spacing). Also included is a full set of "setup" data including instrument primary channel calibration data, all the data defining the derived channels in use, channel names and labels, etc. To minimize the volume of stored data, the actual test data from individual transducer signals are stored as binary numbers whose values are directly related to signal voltage. The data reduction software converts these numbers to engineering units using the stored calibration data.

Data are saved to magnetic tape following each individual test run. Typically, one suspension will undergo about 10 to 12 runs. After testing of the suspension is complete, these data serve as input to the data reduction programs. Usually, the files are copied to the hard disk for data reduction. They may also be copied to floppy disks as the most convenient mode of transporting the data to other IBM-PC-compatible computers. Data from tests of one suspension generally will require three 5-1/4 inch disks.

Raw data files, that is, files saved directly from the test control program, are stored with a '.RAW' designation and are protected from any modification by the data reduction software. The first step of data reduction involves the conversion of '.RAW' files to '.DAT' files which are then used for reduction. This can be accomplished with individual files or in 'batch' mode, allowing easy conversion of a group of files.

The '.DAT' files contain all the information of the '.RAW' files, but '.DAT' files may be altered. All descriptive data and 'setup' data may be edited, and new "derived" data channels may be created in '.DAT' files.

The reduction programs allow for the convenient creation of any number of X-Y data plots from the '.DAT' files. Plots may be produced individually with the operator selecting the ordinate and abscissa variables and plotting scales. Or, plots may be created in batch mode. In the batch mode, data plots for all of the tests run on a given suspension can be produced automatically. A template file describes the specific set of plots to be made for each type of test (vertical, roll, etc.) Each plot is automatically scaled by the program. Examples of data plots produced from tests on a tandem-axle rear suspension are appended to this report.

The data reduction programs include a number of graphical aids for reduction of the data to computer simulation parameters. Using a mouse as an input device, the operator may overlay straight-line segments or polygons on data plots projected on the CRT. On command, the slopes and the end and inflection points of these figures are calculated and displayed in engineering units. This general technique is used to obtain spring rates and spring tables, roll steer, and compliance steer coefficients, etc.

The programs also aid in obtaining the exponential coefficients, i.e., the β coefficients, required by the UMTRI spring model. After the operator generates the spring tables required by the model, and makes an initial estimate of the β's, the program calculates spring force-deflection using the UMTRI model. Results of the calculation are overlayed on the test data on the CRT so that the operator can judge how well the estimated parameters 'fit' the data. The operator iterates using this process until he is satisfied with the results.

A similar iteration process is used to determine auxiliary roll stiffness from roll rate test data. In this process, the roll behavior of the suspension is predicted by a simple model within the program. The model requires predetermined values of spring envelopes and β's, spring spacing, roll center height, and other parameters. The operator chooses the value of auxiliary roll stiffness which provides the best fit of predicted and measured behavior.

All of the system software is hardware specific. Clearly, the test control programs are designed especially for the UMTRI DAS. More to the point, the data reduction programs require a specific, commercially available "graphics card" for the IBM-PC and related graphics software.

SUMMARY

UMTRI has upgraded its Suspension Measurement Facility by adding a digital data-aquisition system to the original analog instrumentation. The addition of this system has improved the efficiency of the facility roughly twofold, allowing reductions of similar magnitude in time required for testing and test costs. Additionally, the data describing the response of the tested suspension can now be made available on readily transportable magnetic medium, in IBM-PC-compatible files. Programs for the convenient display and reduction of these data are available. These data reduction programs are hardware specific in that they require that a particular commercially available "graphics card" be used in the computer system.

APPENDIX A

AXLE ROLL MOMENT MEASUREMENT ON THE UMTRI HEAVY-VEHICLE SUSPENSION MEASUREMENT FACILITY

AXLE ROLL MOMENT MEASUREMENT ON THE UMTRI HEAVY-VEHICLE SUSPENSION MEASUREMENT FACILITY

This document is intended to clarify the meaning of the "Roll Rate" data plots reported as part of the total data package generated during the measurement of suspension properties by UMTRI.

Roll rate plots generally show "Axle Roll Moment" (in-lb) as the ordinate and "Axle Roll Angle" as the abscissa. Axle roll moment is measured in a coordinate system (1) whose origin lies on the intersection of the ground plane and the vertical plane of symmetry of the vehicle body, and (2) which rotates to remain rectilinear to the ground. (Physically, this axis system is the natural reference system of the facility's load cell system.)

This axis system is shown with origin "0" in Figure A-1. Definitions of other notations of Figure A-1 and of the following discussion are:

d:	the partial derivative operator
F_z:	gross axle load (as applied to the load cells). (1/2 of suspension load for tandem suspensions.) (Held fixed during measurement, and a constant for purposes of this discussion.)
h_{RC}:	axle roll center height above ground
K_{RC}:	the effective roll spring rate of the axle about its roll center
K_T:	tire vertical spring rate
1:	Y dimension from the origin to the x-z plane passing through the roll center
M_M:	the measured (plotted) axle roll moment
M_{RC}:	axle roll moment about its roll center
θ_A:	roll angle of the axle
θ_T:	roll angle of the ground (facility table)
RC:	the axle roll center
y_i:	lateral position of the ith tire on the axle

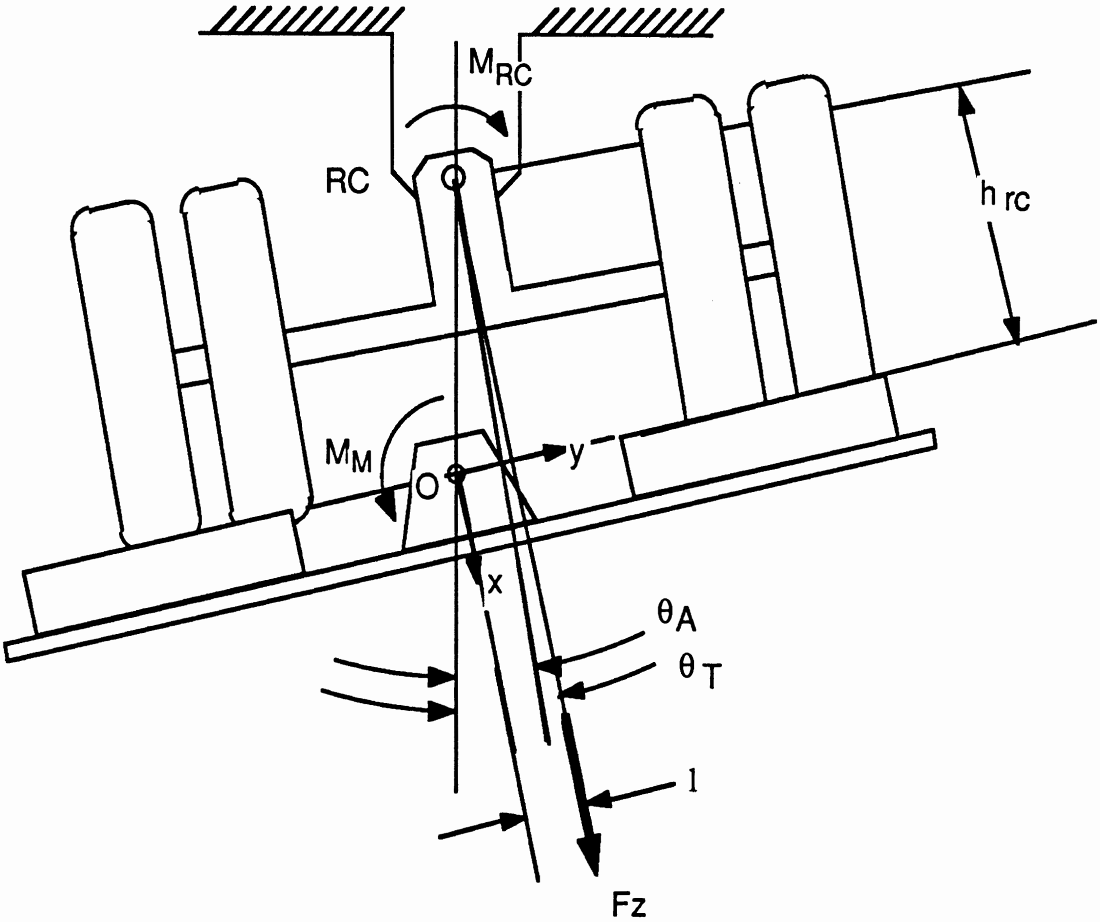
As noted above, the facility's load cell system remains fixed in the table (ground) such that its origin remains on the plane of symmetry of the vehicle body. (Physically, this results from the fact that the table roll pivot is fixed laterally, and the load cells are fixed in the table.) As the geometry and mathematical derivations of Figure A-1 show, the result of this situation is that the roll moment measured by the system is not the roll moment produced by the effective suspension roll spring (about the roll center), but rather that moment plus a moment generated by the y-direction motion of the roll center, and consequential effective y-direction motion of F_z, in the load cell axis system.

The formulations of Figure A-1 demonstrate that the measured roll moment and/or roll rate are too large, and require "correction" by a factor dependent on (1) F_z, (2) h_{RC}, and (3) $d\theta_T/d\theta_A$. (Note that (2) and (3) simply provide the means to calculate 1.) This correction factor tends to be an order of magnitude smaller (10% of) than the measured quantity.

Measurement and reporting procedures have previously provided F_z and h_{RC}. Updated measurement procedures have added the measurement of θ_T which is plotted against θ_A on the "Roll Rate" graph. $d\theta_T/d\theta_A$ is then available as the slope of that plot.

For purposes of correcting previous results, we note that useful estimates of $d\theta_T/d\theta_A$ are easily obtained. Referring to Figure A-2, we see that $d\theta_T/d\theta_A$ is a function of K_{RC}, K_T, and y_i. For purposes of this calculation, the uncorrected suspension roll rate may be used to replace K_{RC}, since the sensitivity of the final result (K_{RC}) to errors in $d\theta_T/d\theta_A$ is small. (Indeed, the estimates of $d\theta_T/d\theta_A = 1.05$ for typical front axles and $d\theta_T/d\theta_A = 1.2$ for typical rear axles are generally reasonable.)

Figure A-1.



Summing moments:

$$M_{RC} - M_M + l \times F_Z = 0$$

Or:

$$M_{RC} = M_M - l \times F_Z$$

But for small values of θ_T

$$l = h_{RC} \times \theta_T$$

Therefore:

$$M_{RC} = M_M - F_Z \times h_{RC} \times \theta_T$$

By definition:

$$K_{RC} = dM_{RC}/d\theta_A$$

Performing the differentiation on the expression for M_{RC} yields:

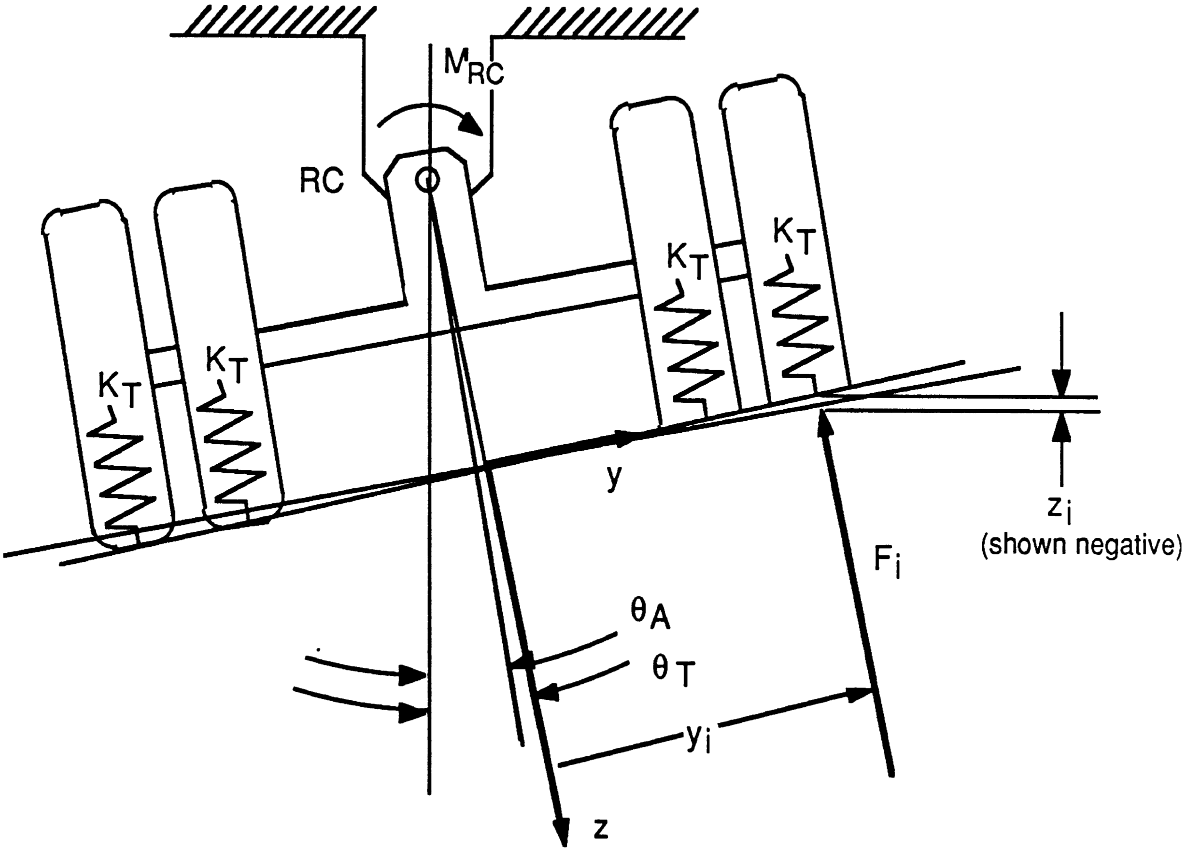
$$K_{RC} = dM_M/d\theta_A - h_{RC} \times F_z \times d\theta_T/d\theta_A$$

Or:

$$K_{RC} = K_{meas} - h_{RC} \times F_z \times d\theta_T/d\theta_A$$

where K_{meas} is the slope of the measured data.

Figure A-2.



(In all cases, $\Sigma = \sum_{i=1}^{NT}$ where NT = number of tires

Summing moments:

$$M_{RC} = \Sigma F_i y_i$$

By definition:

$$K_T = dF_i/dZ_i$$

$$K_{RC} = dM_{RC}/d\theta_A$$

Then:

$$K_{RC} = \Sigma dF_i/d\theta_A y_i = \Sigma dF_i/dZ_i dZ_i/d\theta_A y_i$$

$$K_{RC} = \Sigma K_T y_i dZ_i/d\theta_A$$

From the geometry:

$$dZ_i = y_i d(\theta_T - \theta_A)$$

Then

$$K_{RC} = \Sigma K_T y_i^2 (d\theta_T/d\theta_A - 1)$$

Or

$$d\theta_T/d\theta_A = 1 + K_{RC}/(K_T \Sigma y_i^2)$$

APPENDIX B

EXAMPLE SUSPENSION FACILITY DATA PLOTS

ATE 1- 7-1987 14: 9: 4
YPE OF TEST:VERTICAL
USTOMER:NHTSA
ERATOR:WINKLER
ILE NAME:D:NHTSATRO.DAT
OMMENT:

****

TEST CONDITIONS

ITCH ANGLE= .00
MINAL SUSPENSION LOAD= 0.
UMINAL STEER ANGLE= .00

****

SUSPENSION DATA

PE:4-SPRING LONG EQU
MANUFACTURER:TRAILOR
DEL:?
TING:?
OTHER:4-SPRING WITH LONG EQUALIZER (REAR SLIPER TO REAR SLIPPER)

****

VEHICLE DATA

MANUFACTURER:TRAILOR
ODEL:FLATBED
HER:EUROPEAN (FRANCE) MANUFACTURE

MEASURED DATA

USPENSION	LEADING AXLE	TRAILING AXLE
UNSPRUNG MASS	.00	.00
SPRING LENGTH	37.00	37.00
SPRING SPACING	38.00	38.00
SPRING LASH	.00	.00
TANDEM SPREAD	54.00	54.00

ACILTY	LEADING AXLE	TRAILING AXLE
LATERAL PAD SPACING	72.50	72.38
LATERAL Z-POT SPACING	109.62	107.62
VERTICAL Y-POT POSITION	.00	.00

	LEFT	RIGHT
LONG. PAD SPACING	54.50	54.00

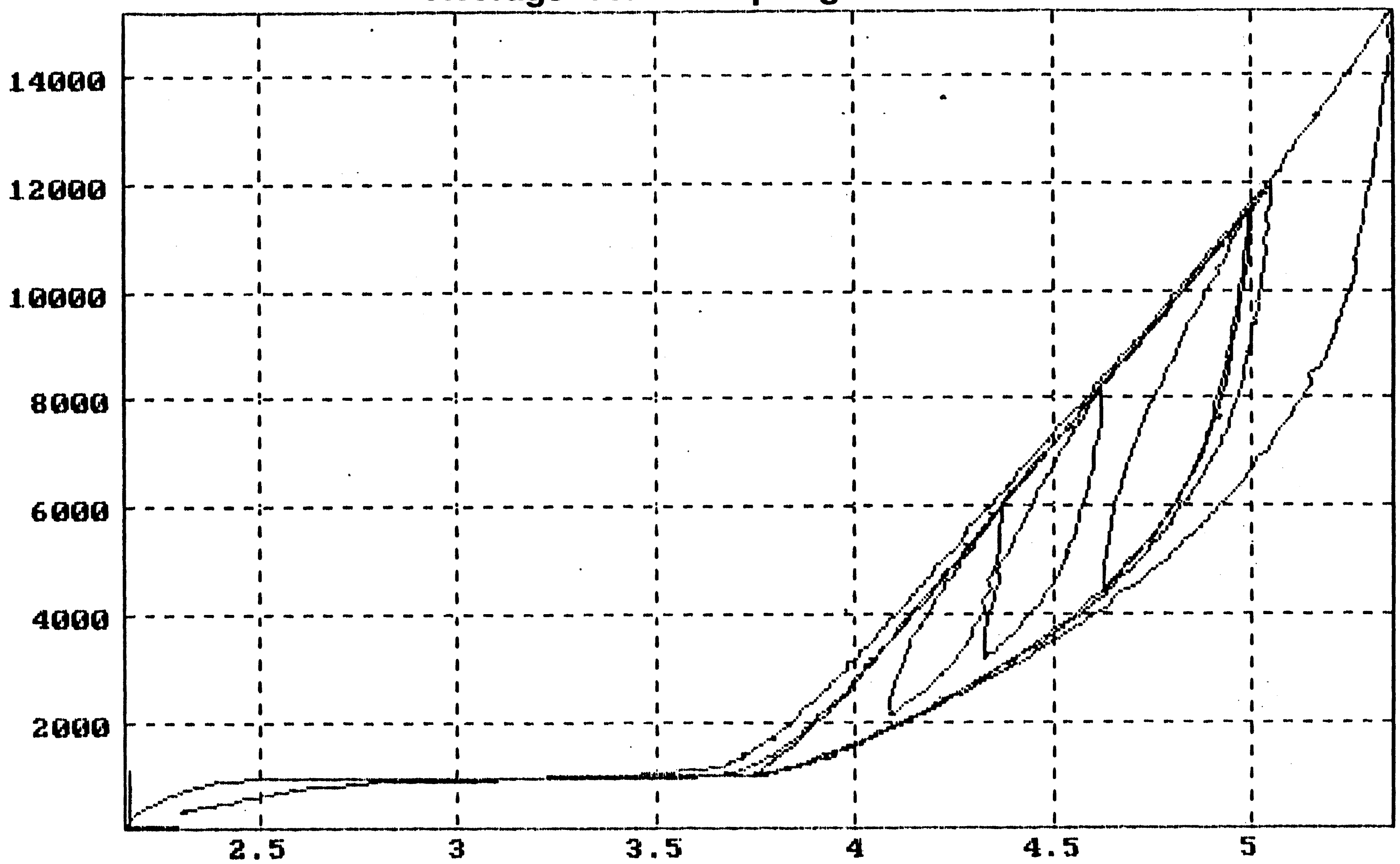
Date: Jan 8, 1987

US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Average Vertical Spring Rate



FZAV 97.41 LBS

FZRA 110.93 LBS

FZLA 83.89 LBS

ZASE 1.94 INCH

ZAAV = 2.17 INCH   FZAV = 97.41 LBS

Ordinate: Average vertical wheel load (FZAV); pounds; spring compression, positive.

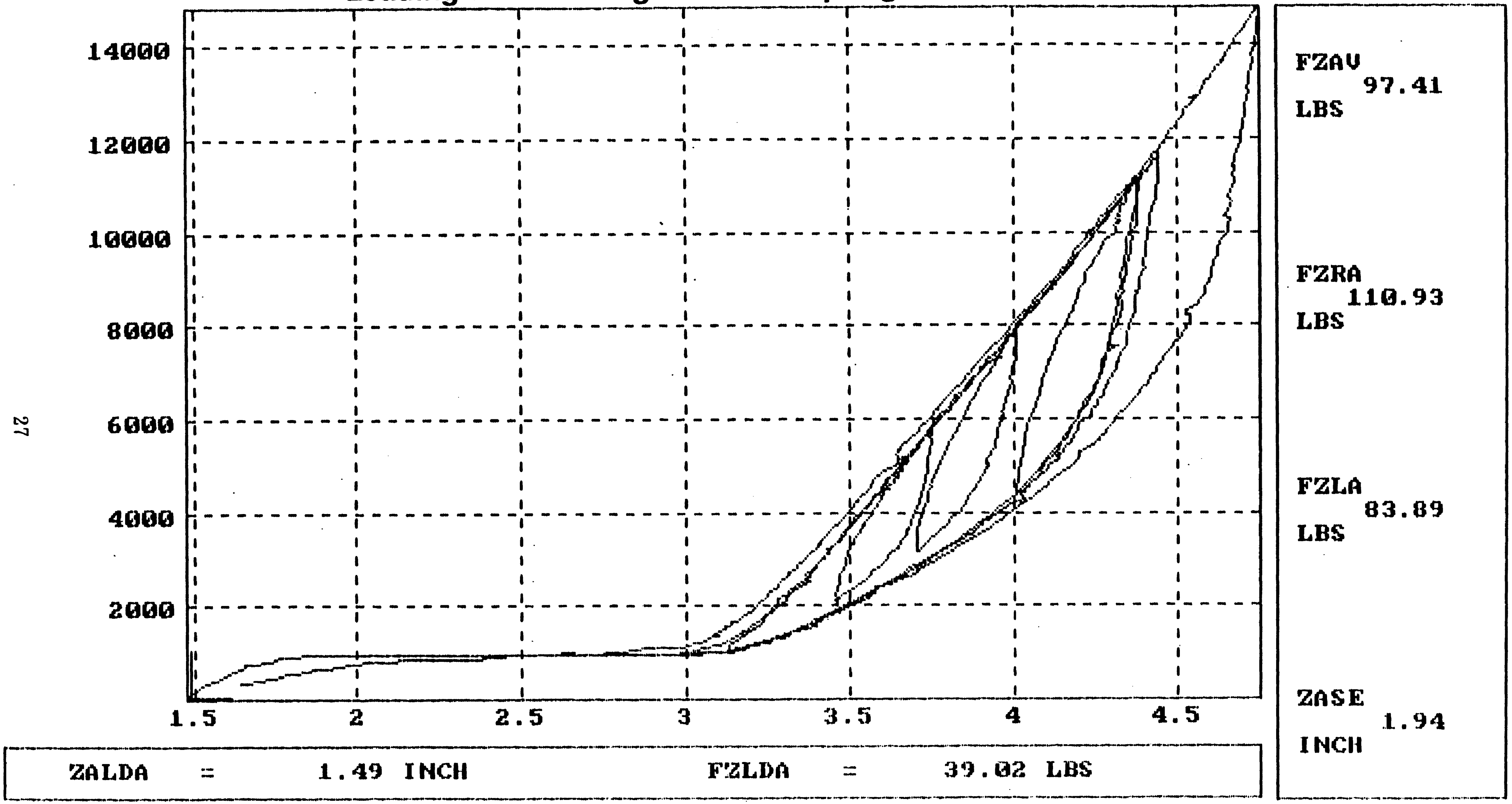
Abscissa: Average vertical axle displacement (ZAAV); inches; spring compression, positive.

US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Leading Axle Average Vertical Spring Rate



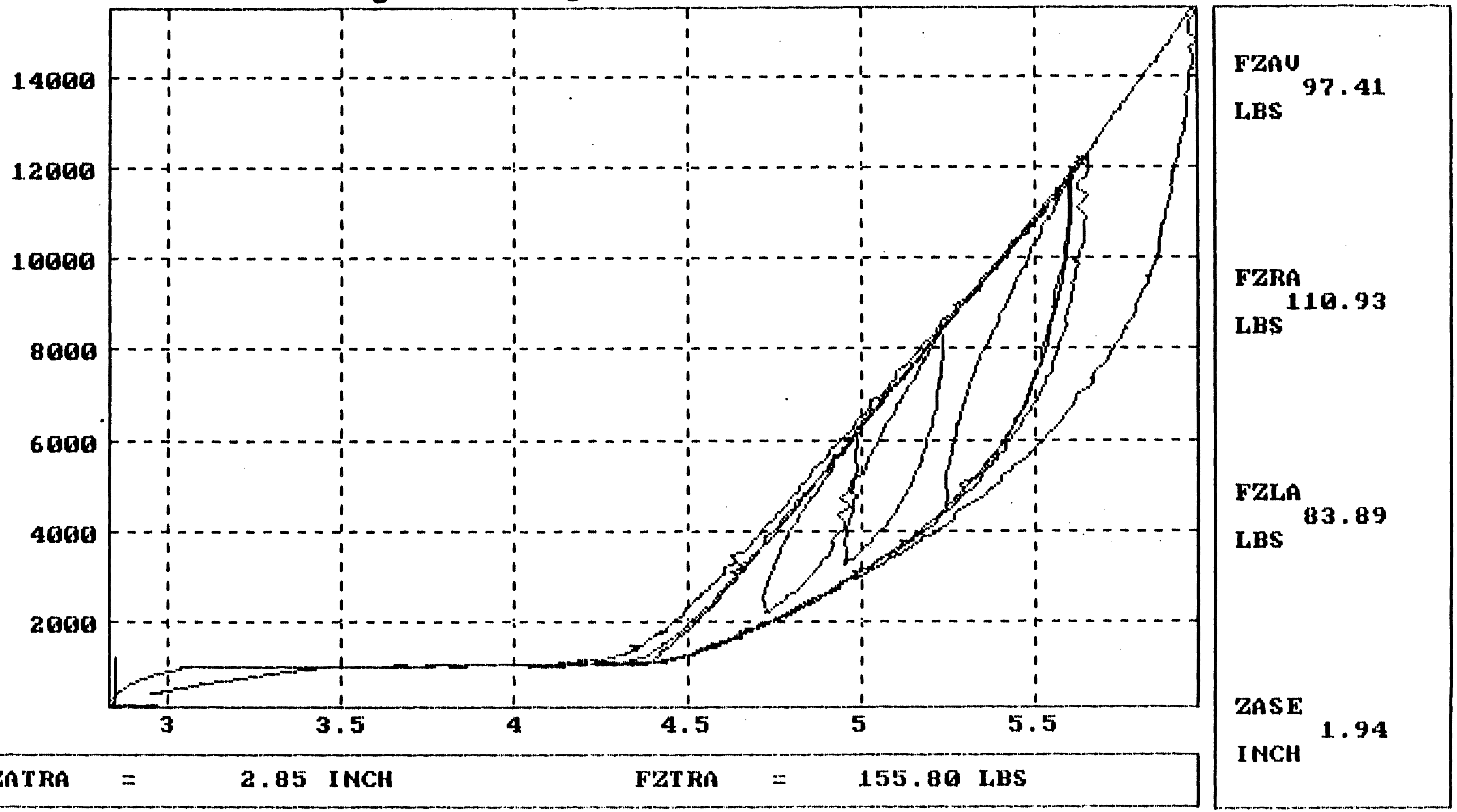
Ordinate: Average leading axle vertical wheel load (FZLDA); pounds; spring compression, positive.
Abscissa: Average leading axle vertical axle displacement (ZALDA); inches; spring compression, positive.

US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Trailing Axle Average Vertical Spring Rate

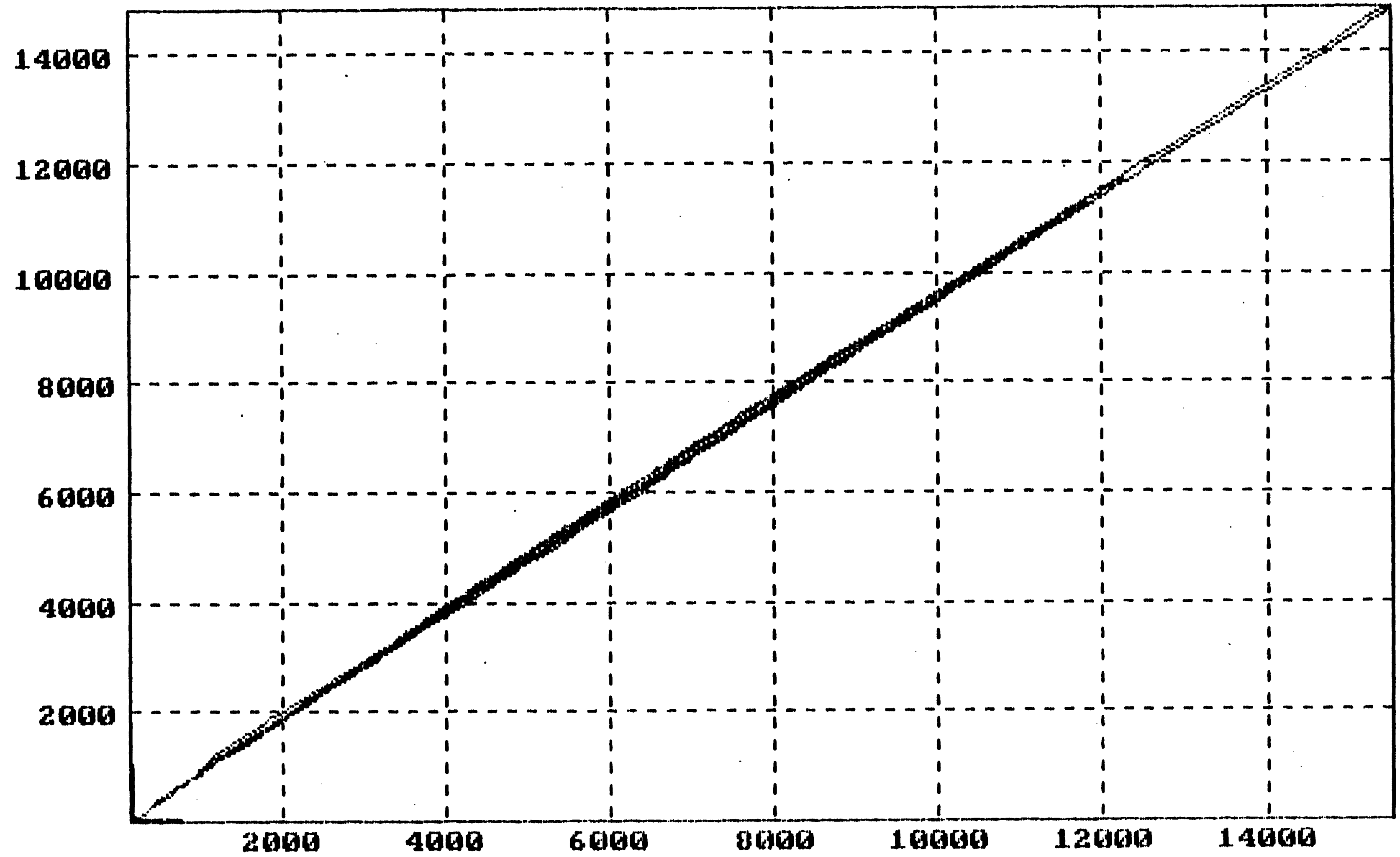


Ordinate: Average trailing axle vertical wheel load (FZTRA); pounds; spring compression, positive.

Abscissa: Average trailing axle vertical axle displacement (ZATRA); inches; spring compression, positive.

US DOT
Trailor (France):Flatbed Trailer   Tandem Rear Suspension   Date: Jan 8, 1987
Pitch = 0.0 degrees

Inter-Axle Load Distribution



FZAV 97.41 LBS

FZRA 110.93 LBS

FZLA 83.89 LBS

ZASE 1.94 INCH

FZTRA = 155.80 LBS   FZLDA = 39.02 LBS

Ordinate: Average leading axle vertical wheel load (FZLDA); pounds; spring compression, positive.
Abscissa: Average trailing axle vertical wheel load (FZTRA); pounds; spring compression, positive.

ATE 1- 7-1987 14:46:36
TYPE OF TEST:ROLL
USTOMER:NHTSA
PERATOR:WINKLER
FILE NAME:D:NHTSATR2.DAT
COMMENT:
****

TEST CONDITIONS

ITCH ANGLE= .00
OMINAL SUSPENSION LOAD=24000.
NOMINAL STEER ANGLE= .00
****

SUSPENSION DATA

TYPE:4-SPRING LONG EQU
MANUFACTURER:TRAILOR
ODEL:?
RATING:?
OTHER:4-SPRING WITH LONG EQUALIZER (REAR SLIPER TO REAR SLIPPER)
****

VEHICLE DATA

MANUFACTURER:TRAILOR
ODEL:FLATBED
OTHER:EUROPEAN (FRANCE) MANUFACTURE

MEASURED DATA

SUSPENSION	LEADING AXLE	TRAILING AXLE
UNSPRUNG MASS	.00	.00
SPRING LENGTH	37.00	37.00
SPRING SPACING	38.00	38.00
SPRING LASH	.00	.00
TANDEM SPREAD	54.00	54.00

FACILTY	LEADING AXLE	TRAILING AXLE
LATERAL PAD SPACING	72.50	72.38
LATERAL Z-POT SPACING	109.62	107.62
VERTICAL Y-POT POSITION	21.88	21.94

	LEFT	RIGHT
LONG. PAD SPACING	54.50	54.00

Date:Jan 8, 1987

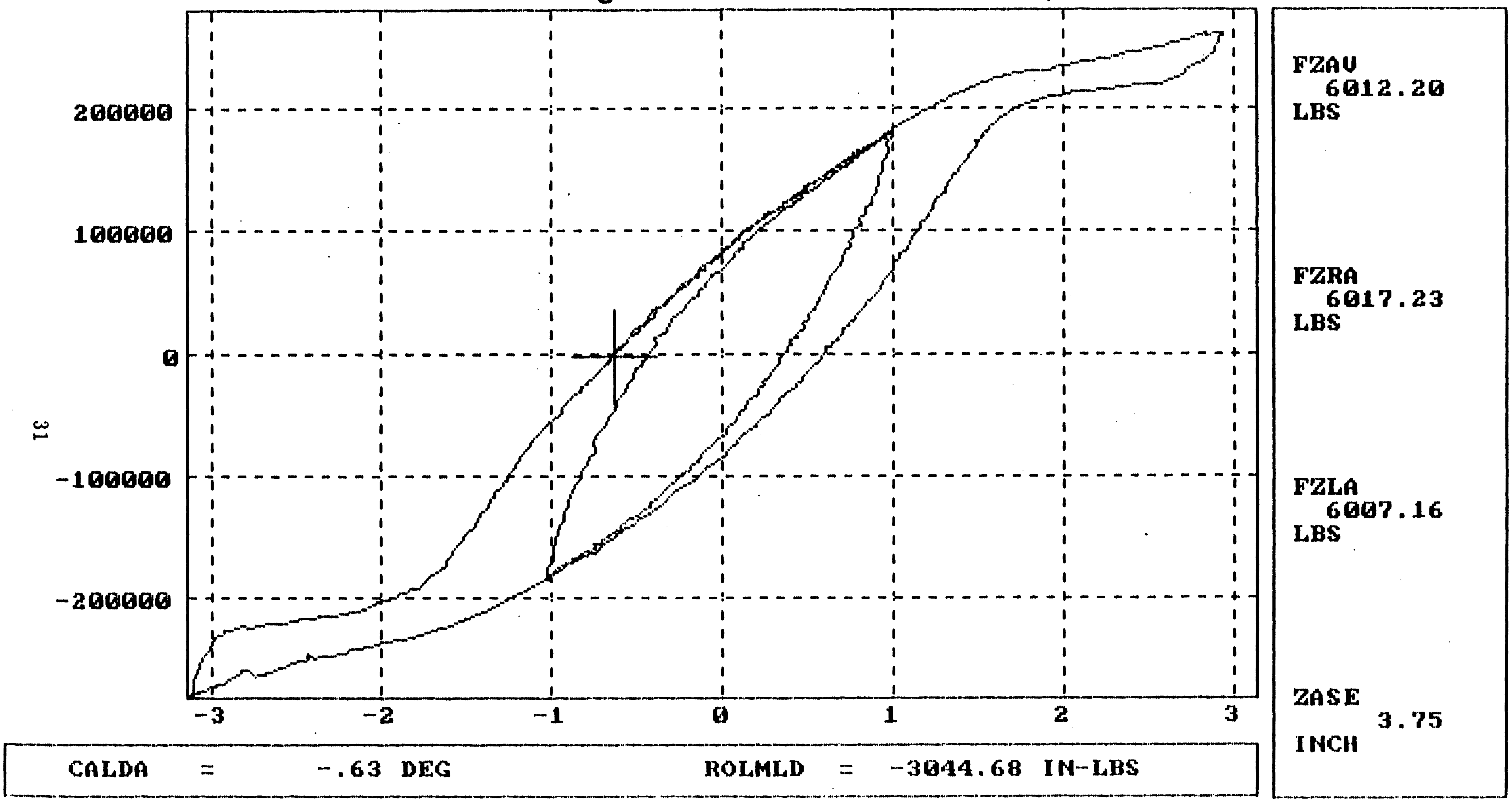
US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Leading Axle Roll Rate

Date: Jan 8, 1987
Pitch = 0.0 degrees

Suspension Load = 24,000 lb.



Ordinate: Leading axle roll moment in load cell coordinate system (ROLMLD); in-lb; right side compressed, positive.

Abscissa: Average leading axle roll (camber) angle (CALDA); degrees; right side compressed, positive.

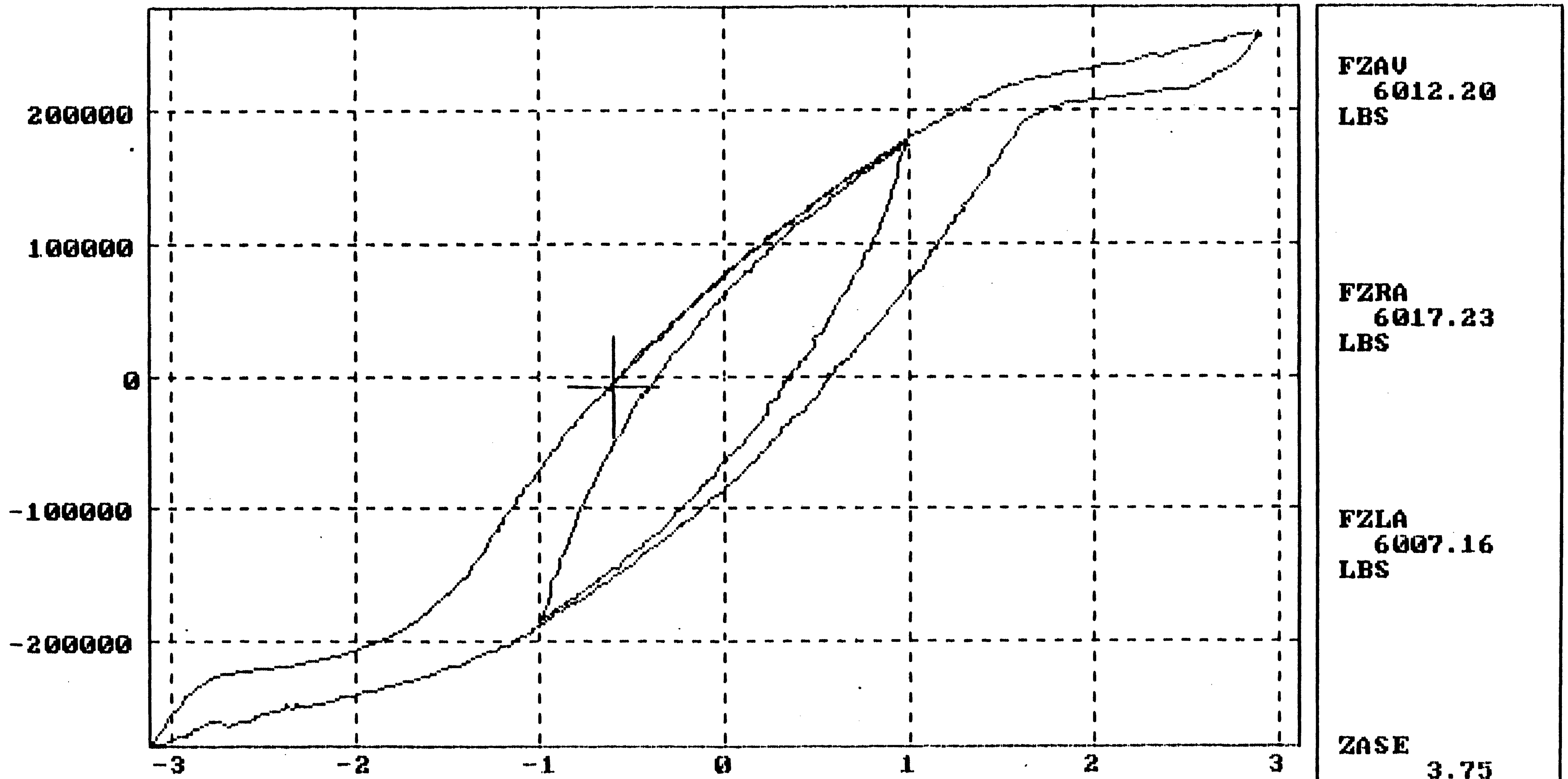
US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Trailing Axle Roll Rate

Suspension Load = 24,000 lb.



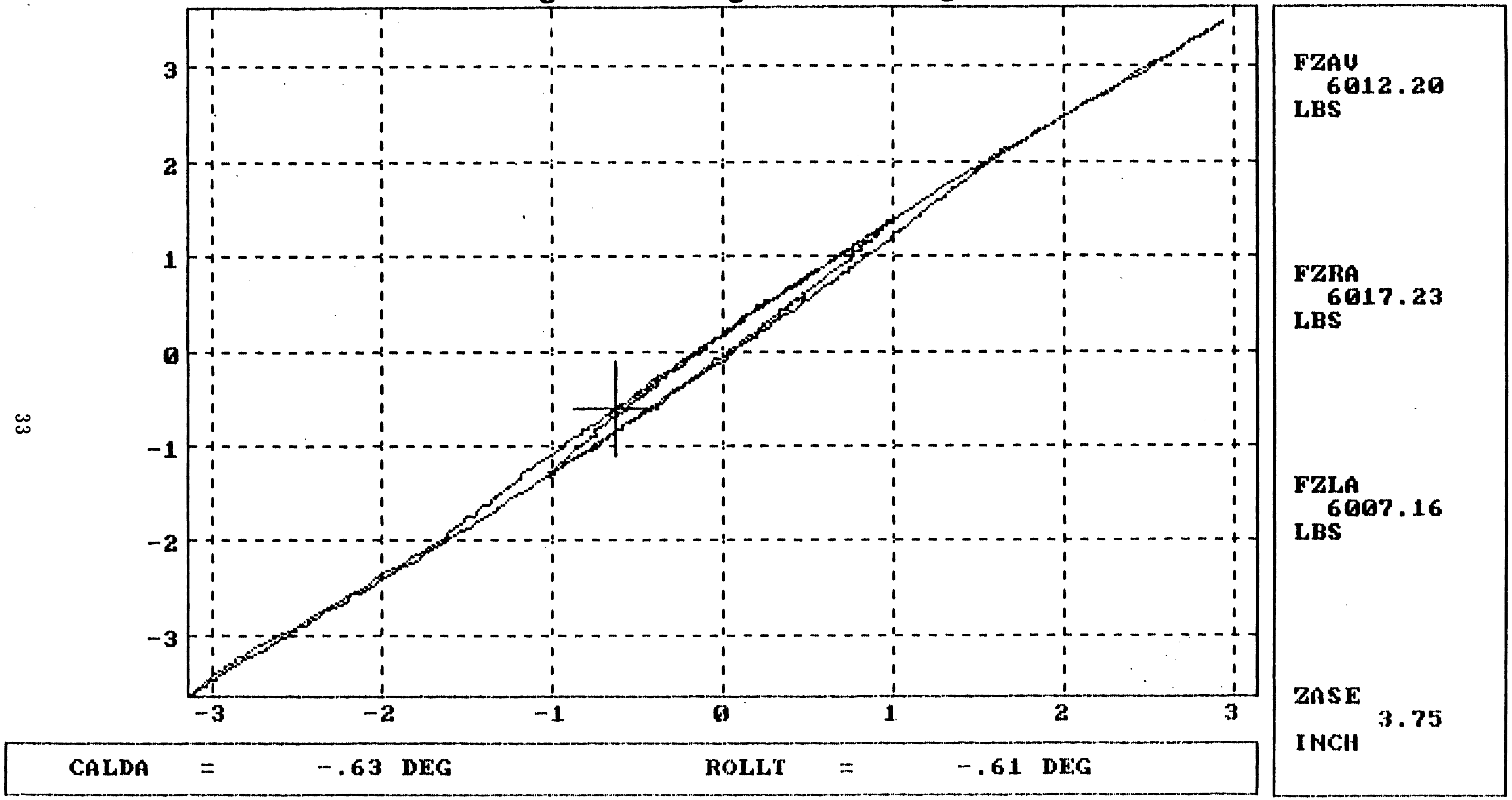
CATRA = -.60 DEG ROLMTR = -7944.42 IN-LBS

Ordinate: Trailing axle roll moment <u>in load cell coordinate system</u> (ROLMTR); in-lb; right side compressed, positive.

Abscissa: Average trailing axle roll (camber) angle (CATRA); degrees; right side compressed, positive.

US DOT
Trailor (France):Flatbed Trailer   Tandem Rear Suspension   Date: Jan 8, 1987
Pitch = 0.0 degrees

Table Roll Angle vs Leading Axle Roll Angle Suspension Load = 24,000 lb.

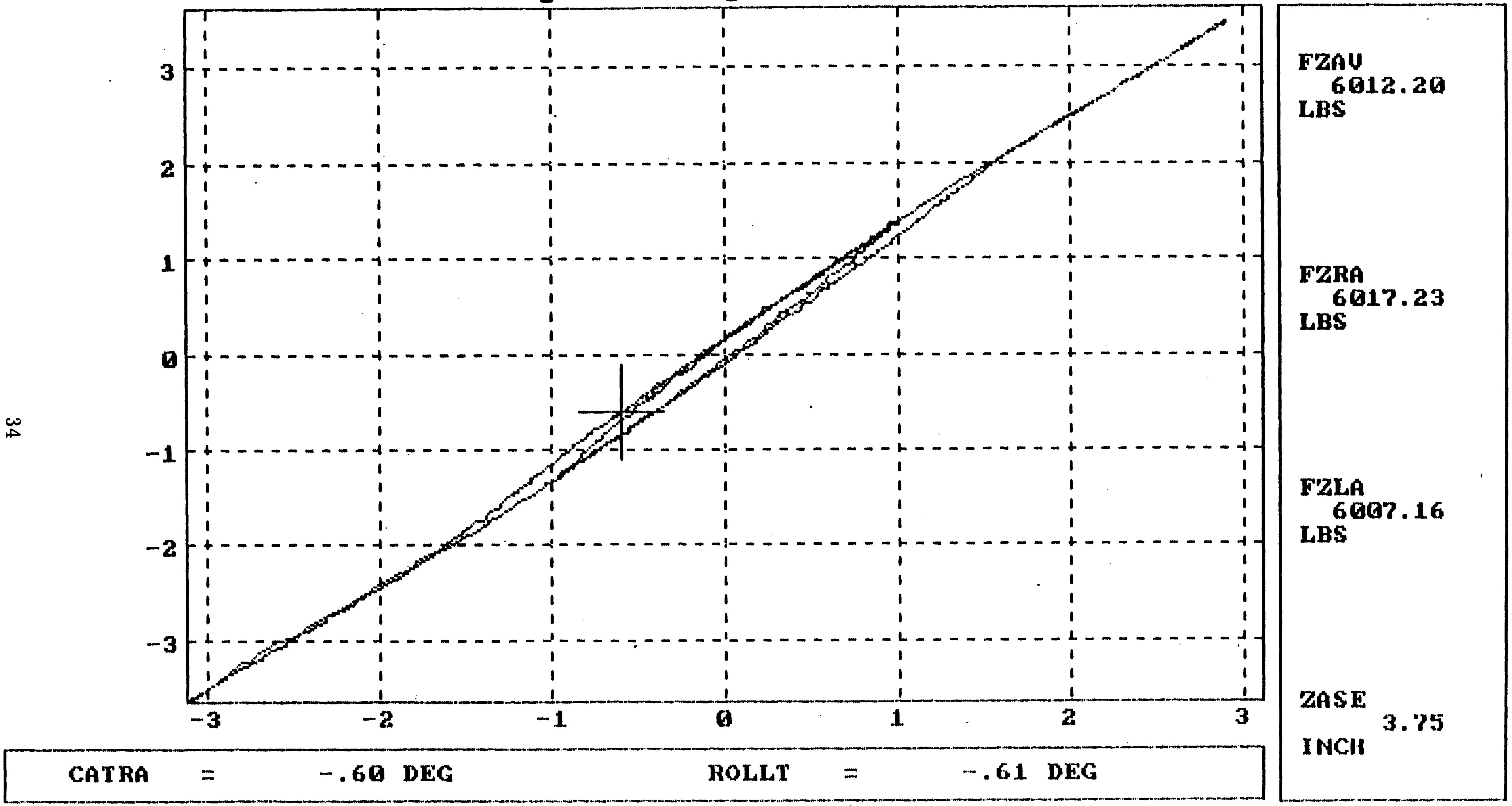


Ordinate: Table roll angle (ROLLT); degrees; right side compressed, positive.
Abscissa: Average leading axle roll (camber) angle (CALDA); degrees; right side compressed, positive.

US DOT
Trailor (France):Flatbed Trailer   Tandem Rear Suspension   Date: Jan 8, 1987
Pitch = 0.0 degrees

Table Roll Angle vs Trailing Axle Roll Angle

Suspension Load = 24,000 lb.



Ordinate: Table roll angle (ROLLT); degrees; right side compressed, positive.
Abscissa: Average trailing axle roll (camber) angle (CATRA); degrees; right side compressed, positive.

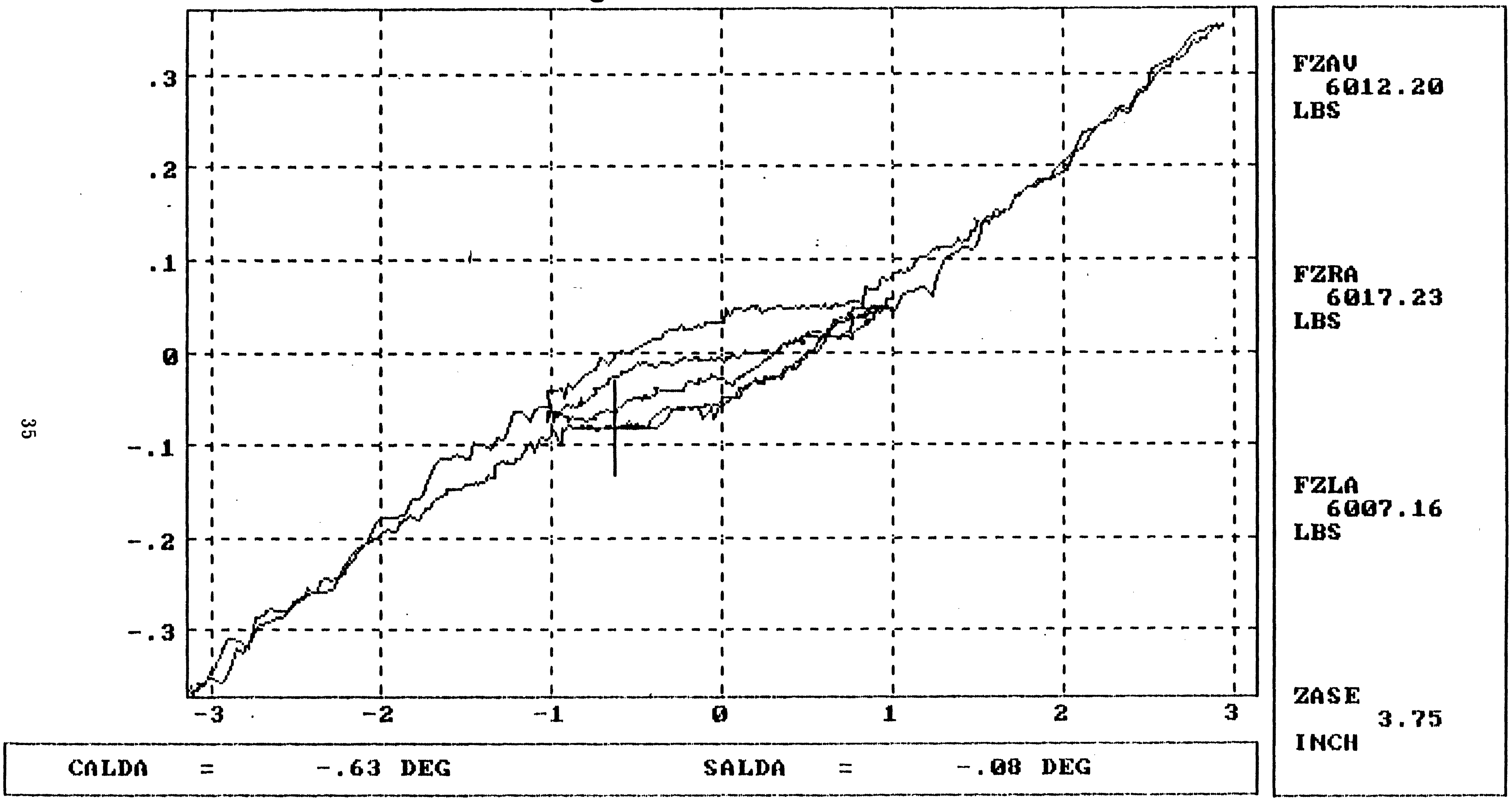
US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Leading Axle Roll Steer

Suspension Load = 24,000 lb.



Ordinate: Average leading axle steer angle (SALDA); degrees; steer toward right, positive.

Abscissa: Average leading axle roll (camber) angle (CALDA); degrees; right side compressed, positive.

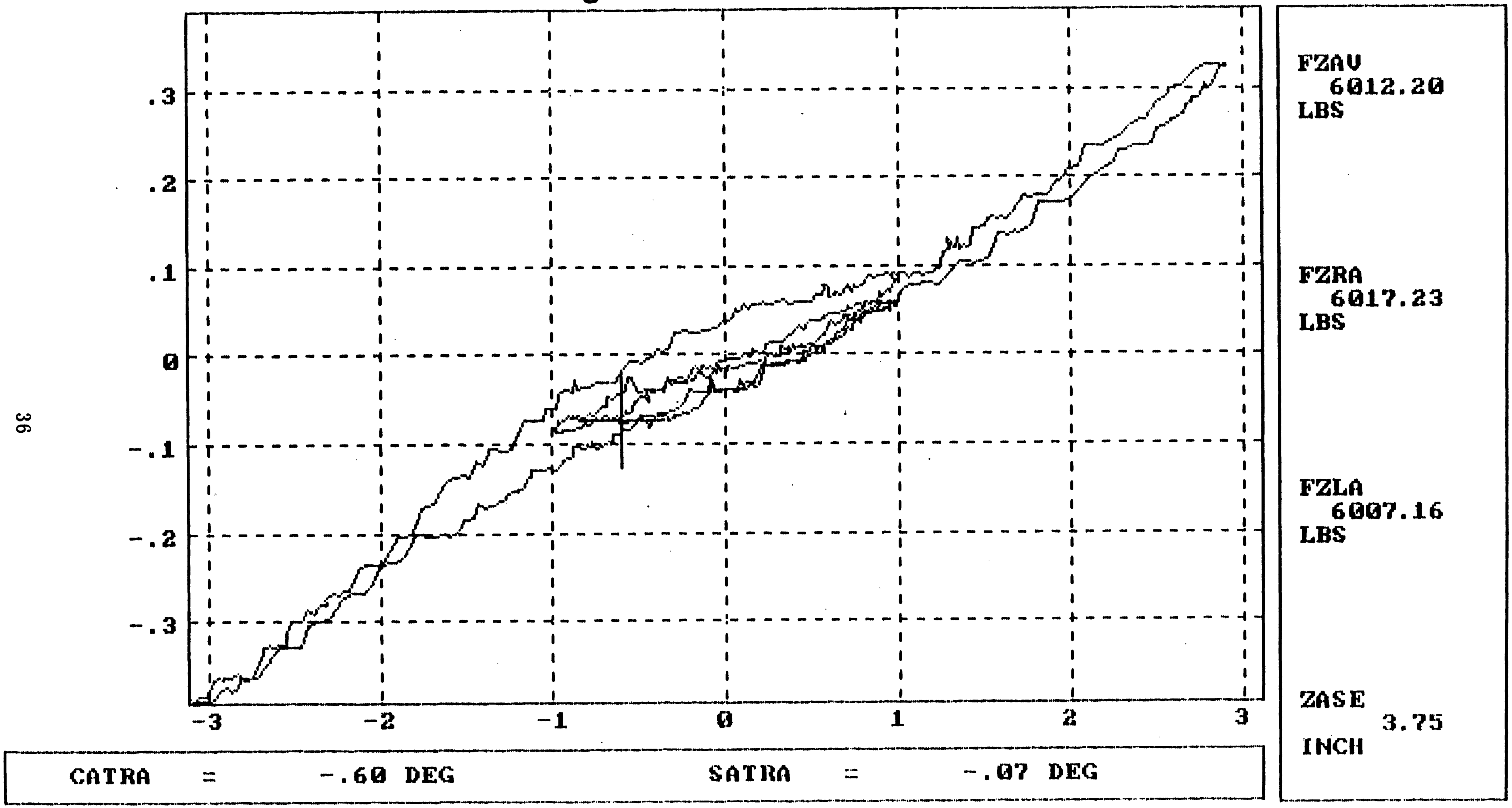
US DOT
Trailor (France):Flatbed Trailer

Tandem Rear Suspension

Trailing Axle Roll Steer

Date: Jan 8, 1987
Pitch = 0.0 degrees

Suspension Load = 24,000 lb.



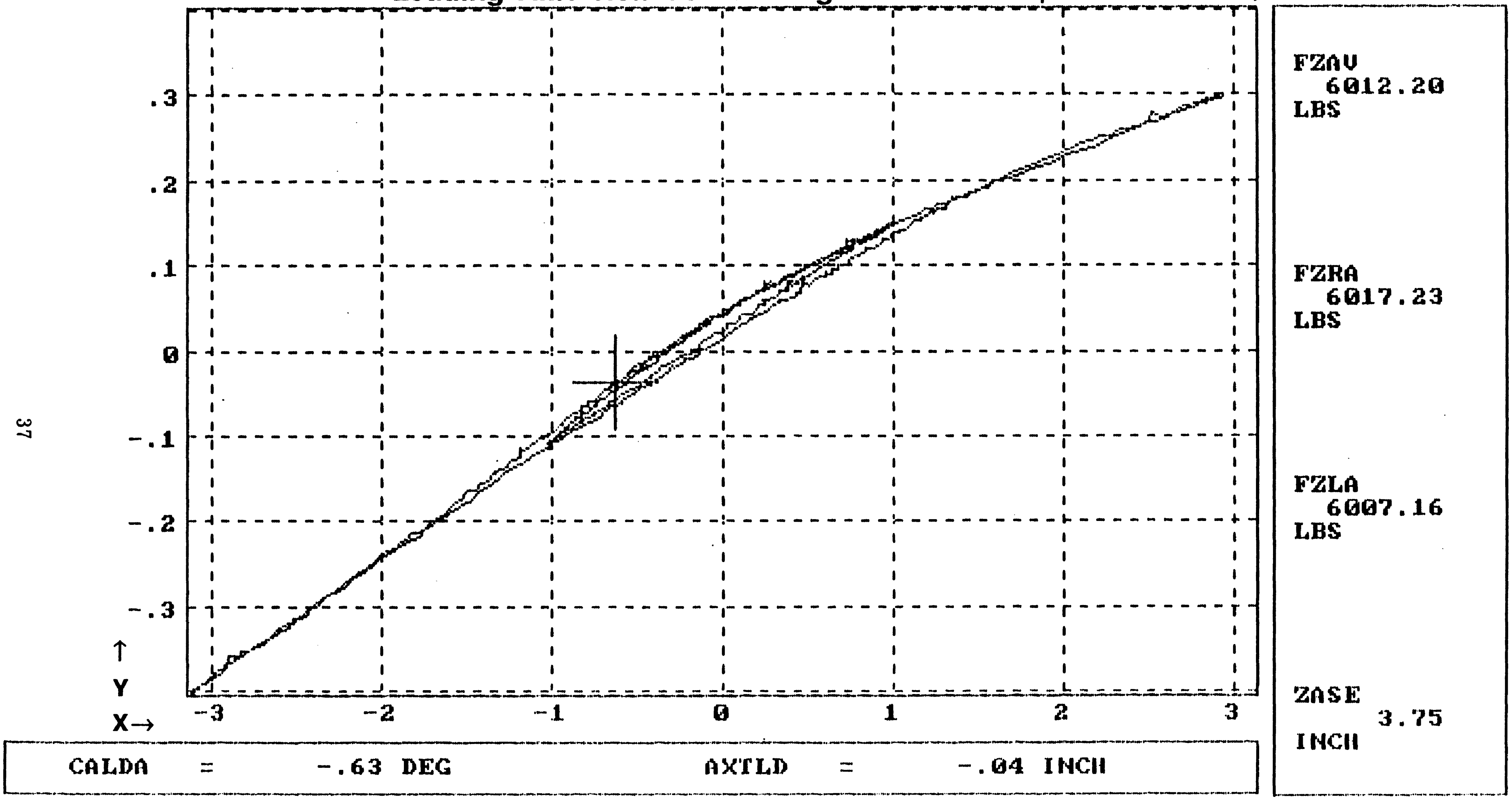
Ordinate: Average trailing axle steer angle (SATRA); degrees; steer toward right, positive.
Abscissa: Average trailing axle roll (camber) angle (CATRA); degrees; right side compressed, positive.

NHTSA: US DOT
Trailor (France): Flatbed Trailer Tandem Rear Suspension

Date: January 13, 1987 (reprint)
Pitch = 0.0 degrees

Leading Axle Roll Center Height

Suspension Load = 24,000 lb.



Abscissa (X): Average leading axle roll (camber) angle (CALDA); degrees; right side compressed, positive.

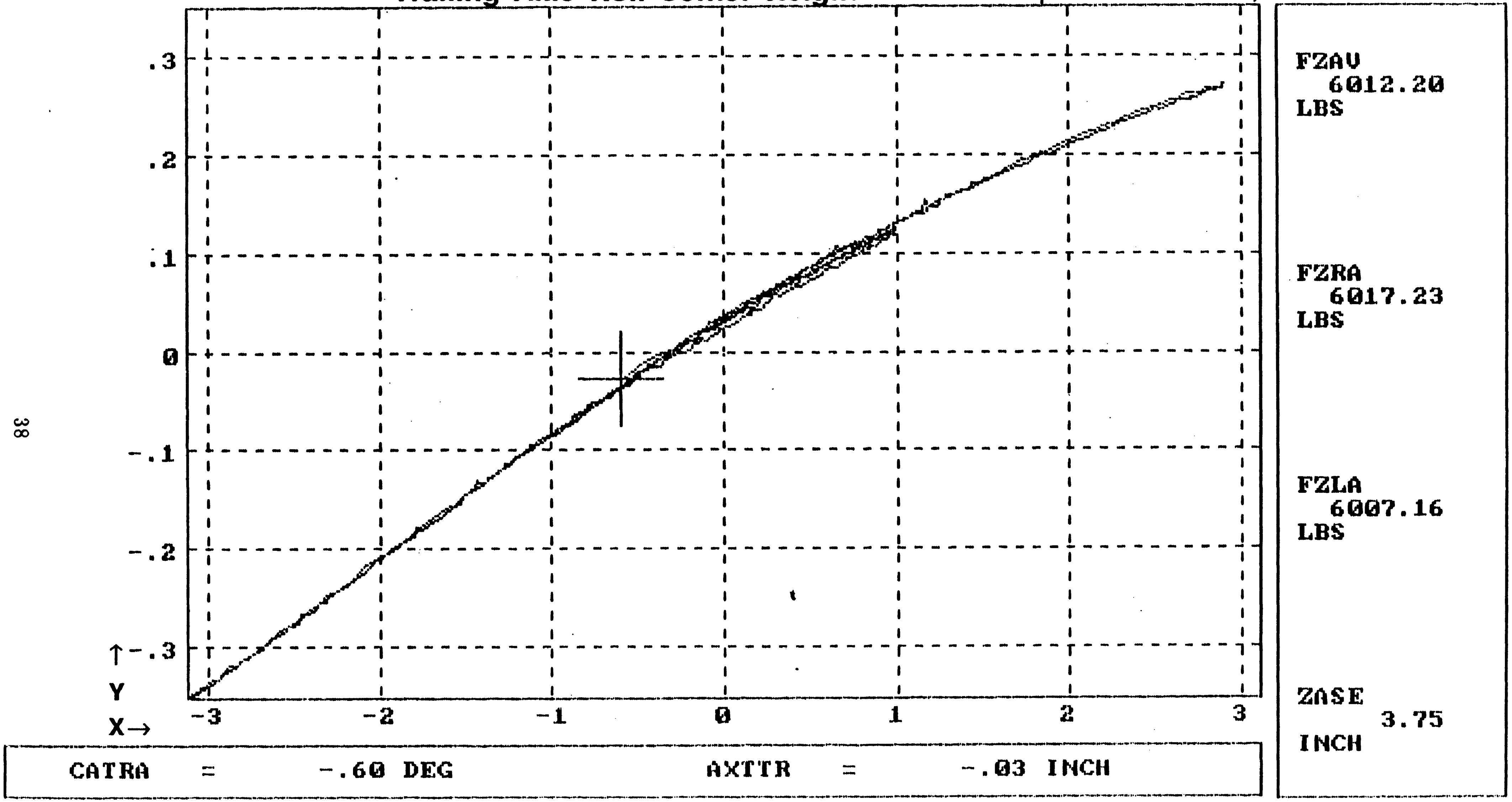
Ordinate (Y): Leading axle lateral translation (AXTLD) at a position 21.88 inches above the ground; inches; motion toward right, positive.

NHTSA: US DOT
Trailor (France): Flatbed Trailer Tandem Rear Suspension

Date: January 13, 1987 (reprint)
Pitch = 0.0 degrees

Trailing Axle Roll Center Height

Suspension Load = 24,000 lb.



Abscissa (X): Average trailing axle roll (camber) angle (CATRA); degrees; right side compressed, positive.
Ordinate (Y): Trailing axle lateral translation (AXTTR) at a position 21.94 inches above the ground; inches; motion toward right, positive.

DATE 1- 7-1987 14:56:28
TYPE OF TEST:ALIGNING MOMENT
CUSTOMER:NHTSA
OPERATOR:WINKLER
FILE NAME:D:NHTSATR4.DAT
COMMENT:

****

TEST CONDITIONS

PITCH ANGLE= .00
NOMINAL SUSPENSION LOAD=38000.
NOMINAL STEER ANGLE= .00

****

SUSPENSION DATA

TYPE:4-SPRING LONG EQU
MANUFACTURER:TRAILOR
MODEL:?
RATING:?
OTHER:4-SPRING WITH LONG EQUALIZER (REAR SLIPER TO REAR SLIPPER)

****

VEHICLE DATA

MANUFACTURER:TRAILOR
MODEL:FLATBED
OTHER:EUROPEAN (FRANCE) MANUFACTURE

MEASURED DATA

SUSPENSION	LEADING AXLE	TRAILING AXLE
UNSPRUNG MASS	.00	.00
SPRING LENGTH	37.00	37.00
SPRING SPACING	38.00	38.00
SPRING LASH	.00	.00
TANDEM SPREAD	54.00	54.00

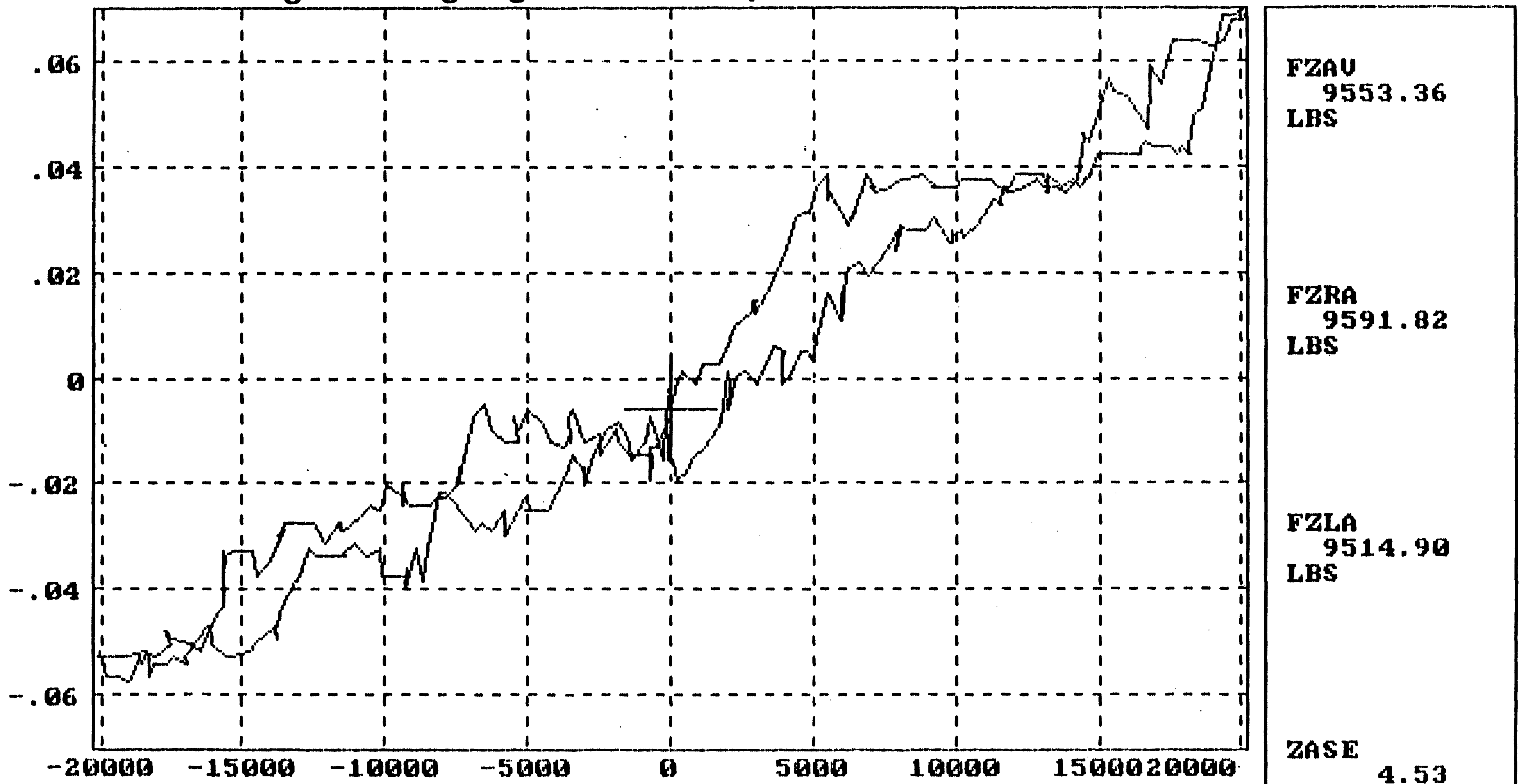
FACILTY	LEADING AXLE	TRAILING AXLE
LATERAL PAD SPACING	72.50	72.38
LATERAL Z-POT SPACING	109.62	107.62
VERTICAL Y-POT POSITION	22.62	22.62
	LEFT	RIGHT
LONG. PAD SPACING	54.50	54.00

Date: Jan 8, 1987

US DOT
Trailor (France):Flatbed Trailer Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Leading Axle Aligning Moment Compliance Steer Suspension Load = 38,000 lb.



MZLDA = -31.06 IN-LBS SALDA = -.01 DEG

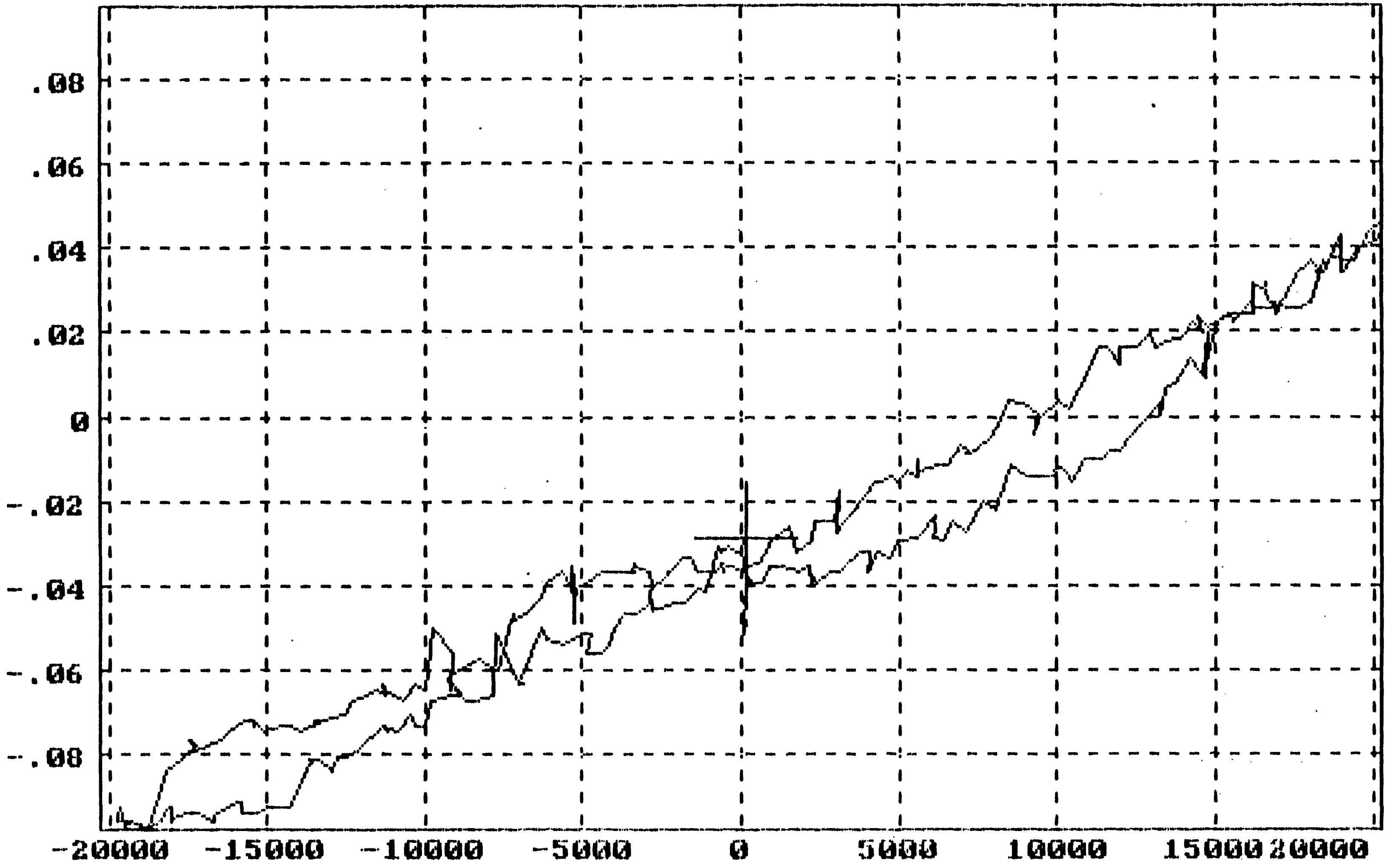
Ordinate: Average leading axle steer angle (SALDA); degrees; steer toward right, positive.

Abscissa: Average leading axle aligning moment (MZLDA); in-lb per wheel set; applied to all four wheel sets simultaneously; downward (right hand rule) moment vector, positive.

US DOT
Trailor (France):Flatbed Trailer Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Trailing Axle Aligning Moment Compliance Steer Suspension Load = 38,000 lb.



FZAV
9553.36
LBS

FZRA
9591.82
LBS

FZLA
9514.90
LBS

ZASE
4.53
INCH

MZTRA = 123.93 IN-LBS SATRA = -.03 DEG

Ordinate: Average trailing axle steer angle (SATRA); degrees; steer toward right, positive.

Abscissa: Average trailing axle aligning moment (MZTRA); in-lb per wheel set; applied to all four wheel sets simultaneously; downward (right hand rule) moment vector, positive.

DATE 1- 7-1987 15:28:22
TYPE OF TEST:LONGITUDINAL FORCE
CUSTOMER:NHTSA
OPERATOR:WINKLER
FILE NAME:D:NHTSATR8.DAT
COMMENT:

****

TEST CONDITIONS

PITCH ANGLE= .00
NOMINAL SUSPENSION LOAD=38000.
NOMINAL STEER ANGLE= .00

****

SUSPENSION DATA

TYPE:4-SPRING LONG EQU
MANUFACTURER:TRAILOR
MODEL:?
RATING:?
OTHER:4-SPRING WITH LONG EQUALIZER (REAR SLIPER TO REAR SLIPPER)

****

VEHICLE DATA

MANUFACTURER:TRAILOR
MODEL:FLATBED
OTHER:EUROPEAN (FRANCE) MANUFACTURE

MEASURED DATA

SUSPENSION	LEADING AXLE	TRAILING AXLE
UNSPRUNG MASS	.00	.00
SPRING LENGTH	37.00	37.00
SPRING SPACING	38.00	38.00
SPRING LASH	.00	.00
TANDEM SPREAD	54.00	54.00

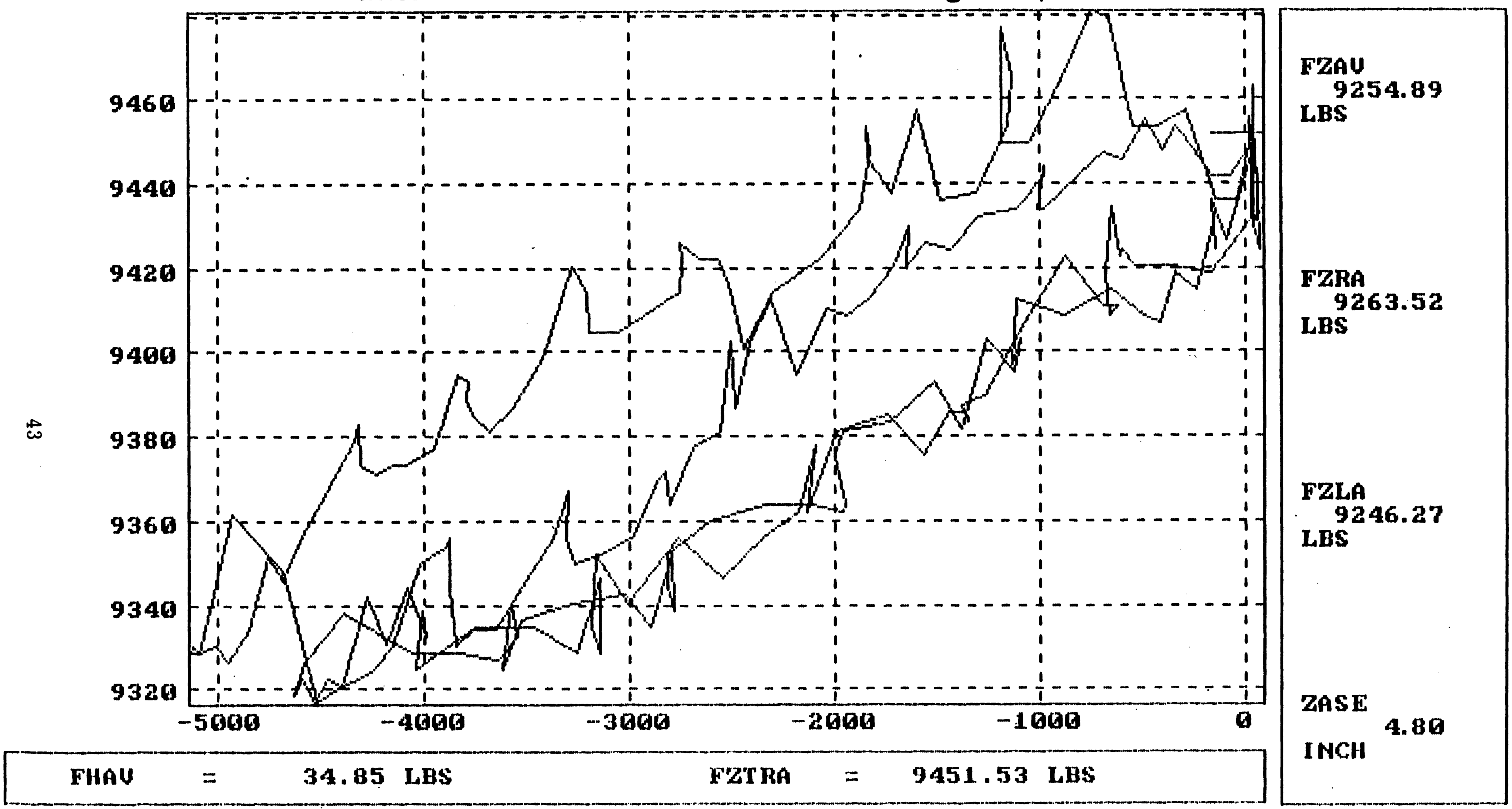
FACILTY	LEADING AXLE	TRAILING AXLE
LATERAL PAD SPACING	72.50	72.38
LATERAL Z-POT SPACING	109.62	107.62
VERTICAL Y-POT POSITION	22.62	22.62
	LEFT	RIGHT
LONG. PAD SPACING	54.50	54.00

Date: Jan 8, 1987

US DOT
Trailor (France):Flatbed Trailer — Tandem Rear Suspension

Date: Jan 8, 1987
Pitch = 0.0 degrees

Inter-Axle Load Transfer Due To Braking — Suspension Load = 38,000 lb.



Ordinate: Average trailing axle vertical wheel load (FZTRA); pounds; spring compression, positive.

Abscissa: Average longitudinal force (FHAV); lb per wheel set; applied to all four wheel sets simultaneously; braking force, negative.